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THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

MAGNALIA NATURÆ; OR, THE GREATER PROBLEMS OF BIOLOGY[1]

The science of zoology, all the more the incorporate science of biology, is no simple affair, and from its earliest beginnings it has been a great and complex and many-sided thing. We can scarce get a broader view of it than from Aristotle, for no man has ever looked upon our science with a more far-seeing and comprehending eye. Aristotle was all things that we mean by "naturalist" or "biologist." He was a student of the ways and doings of beast and bird and creeping thing; he was morphologist and embryologist; he had the keenest insight into physiological problems, though lacking that knowledge of the physical sciences without which physiology can go but a little way: he was the first and is the greatest of psychologists; and in the light of his genius biology merged in a great philosophy.

I do not for a moment suppose that the vast multitude of facts which Aristotle records were all, or even mostly, the fruit of his own immediate and independent observation. Before him were the Hippocratic and other schools of physicians and anatomists. Before him there were nameless and forgotten Fabres, Röesels, Réaumurs and Hubers, who observed the habits, the diet and the habitations of the sand-wasp or the mason-bee; who traced out the little lives, and discerned the vocal organs, of grasshopper and cicada; and who, together with generations of bee-keeping

[1] Address of the president to the Zoological Section. Portsmouth, 1911.

peasants, gathered up the lore and wisdom of the bee. There were fishermen skilled in all the cunning of their craft, who discussed the wanderings of tunny and mackerel, sword-fish or anchovy; who argued over the ages, the breeding-places and the food of this fish or that; who knew how the smooth dogfish breeds two thousand years before Johannes Müller; who saw how the male pipe-fish carries its young before Cavolini; and who had found the nest of the nest-building rock-fishes before Gerbe rediscovered it almost in our own day. There were curious students of the cuttle-fish (I sometimes imagine they may have been priests of that sea-born goddess to whom the creatures were sacred) who had diagnosed the species, recorded the habits and dissected the anatomy of the group, even to the discovery of that strange hectocotylus arm that baffled Della Chiaje, Cuvier and Koelliker, and that Verany and Heinrich Müller reexplained.

All this varied learning Aristotle gathered up and wove into his great web. But every here and there, in words that are unmistakably the master's own, we hear him speak of what are still the great problems and even the hidden mysteries of our science; of such things as the nature of variation, of the struggle for existence, of specific and generic differentiation of form, of the origin of the tissues, the problems of heredity, the mystery of sex, of the phenomena of reproduction and growth, the characteristics of habit, instinct and intelligence, and of the very meaning of life itself. Amid all the maze of concrete facts that century after century keeps adding to our store, these, and such as these, remain the great mysteries of natural science—the *Magnalia naturæ,* to borrow a great word from Bacon, who in his turn had borrowed it from St. Paul.

Not that these are the only great problems for the biologist, nor that there is even but a single class of great problems in biology. For Bacon himself speaks of the *magnalia naturæ, quoad usus humanos,* the study of which has for its objects "the prolongation of life or the retardation of age, the curing of diseases counted incurable, the mitigation of pain, the making of new species and transplanting of one species into another," and so on through many more. Assuredly I have no need to remind you that a great feature of this generation of ours has been the way in which biology has been justified of her children, in the work of those who have studied the *magnalia naturæ, quoad usus humanos.*

But so far are biologists from being nowadays engrossed in practical questions, in applied and technical zoology, to the neglect of its more recondite problems, that there never was a time when men thought more deeply or labored with greater zeal over the fundamental phenomena of living things; never a time when they reflected in a broader spirit over such questions as purposive adaptation, the harmonious working of the fabric of the body in relation to environment and the interplay of all the creatures that people the earth; over the problems of heredity and variation; over the mysteries of sex and the phenomena of generation and reproduction, by which phenomena, as the wise woman told, or reminded, Socrates, and as Harvey said again (and for that matter, as Coleridge said, and Weismann, but not quite so well) —by which, as the wise old woman said, we gain our glimpse of insight into eternity and immortality. These then, together with the problem of the origin of species, are indeed *magnalia naturæ;* and I take it that inquiry into these, deep and wide research specially directed to the solution of these, is characteristic of the spirit of our

time, and is the pass-word of the younger generation of biologists.

Interwoven with this high aim which is manifested in the biological work of recent years is another tendency. It is the desire to bring to bear upon our science, in greater measure than before, the methods and results of the other sciences, both those that in the hierarchy of knowledge are set above and below, and those that rank alongside of our own.

Before the great problems of which I have spoken, the cleft between zoology and botany fades away, for the same problems are common to the two sciences. When the zoologist becomes a student not of the dead but of the living, of the vital processes of the cell rather than of the dry bones of the body, he becomes once more a physiologist, and the gulf between these two disciplines disappears. When he becomes a physiologist, he becomes, *ipso facto,* a student of chemistry and of physics. Even mathematics has been pressed into the service of the biologist, and the calculus of probabilities is not the only branch of mathematics to which he may usefully appeal.

The physiologist has long had as his distinguishing characteristic, giving his craft a rank superior to the sister branch of morphology, the fact that in his great field of work, and in all the routine of his experimental research, the methods of the physicist and the chemist, the lessons of the anatomist, and the experience of the physician are inextricably blended in one common central field of investigation and thought. But it is much more recently that the morphologist and embryologist have made use of the method of experiment, and of the aid of the physical and chemical sciences—even of the teachings of philosophy: all in order to probe into properties of the living organism that men were wont to take for granted, or to regard as beyond their reach, under a narrower interpretation of the business of the biologist. Driesch and Loeb and Roux are three among many men who have become eminent in this way in recent years, and their work we may take as typical of methods and aims such as those of which I speak. Driesch, both by careful experiment and by philosophic insight, Loeb, by his conception of the dynamics of the cell and by his marvellous demonstrations of chemical and mechanical fertilization, Roux, with his theory of auto-determination, and by all the labors of the school of *Entwickelungsmechanik* which he has founded, have all in various ways, and from more or less different points of view, helped to reconstruct and readjust our ideas of the relations of embryological processes, and hence of the phenomenon of life itself, on the one hand to physical causes (whether external to or latent in the mechanism of the cell), or on the other to the ancient conception of a vital element alien to the province of the physicist.

No small number of theories or hypotheses, that seemed for a time to have been established on ground as firm as that on which we tread, have been reopened in our day. The adequacy of natural selection to explain the whole of organic evolution has been assailed on many sides; the old fundamental subject of embryological debate between the evolutionists or preformationists (of the school of Malpighi, Haller and Bonnet) and the advocates of epigenesis (the followers of Aristotle, of Harvey, of Caspar F. Wolff and of Von Baer) is now discussed again, in altered language, but as a pressing question of the hour; the very foundations of the cell-theory have been scrutinized to decide, for instance, whether the segmented ovum, or even the complete organism, be a colony of quasi-independent cells, or a living unit in which cell differ-

entiation is little more than a superficial phenomenon; the whole meaning, bearing and philosophy of evolution has been discussed by Bergson, on a plane to which neither Darwin nor Spencer ever attained; and the hypothesis of a vital principle, or vital element, that had lain in the background for near a hundred years, has come into men's mouths as a very real and urgent question, the greatest question for the biologist of all.

In all ages the mystery of organic form, the mystery of growth and reproduction, the mystery of thought and consciousness, the whole mystery of the complex phenomena of life, have seemed to the vast majority of men to call for description and explanation in terms alien to the language which we apply to inanimate things; though at all times there have been a few who sought, with the materialism of Democritus, Lucretius or Giordano Bruno, to attribute most, or even all, of these phenomena to the category of physical causation.

For the first scientific exposition of vitalism, we must go back to Aristotle, and to his doctrine of the three parts of the tripartite soul: according to which doctrine, in Milton's language, created things "by grandual change sublimed, To vital spirits aspire, to animal, To intellectual!" The first and lowest of these three, the *ψυχὴ ἡ θρεπτική*, by whose agency nutrition is effected, is *ἡ πρώτη ψυχή*, the inseparable concomitant of life itself. It is inherent in the plant as well as in the animal and in the Linnean aphorism, *Vegetabilia crescunt et vivunt*, its existence is admitted in a word. Under other aspects, it is all but identical with the *ψυχὴ αὐξητική* and *γεννητική* the soul of growth and of reproduction: and in this composite sense it is no other than Driesch's "Entelechy," the hypothetic natural agency that presides over the form and formation of the body. Just as Driesch's psychoid or psychoids, which are the basis of instinctive phenomena, of sensation, instinct, thought, reason, and all that directs that body which entelechy has formed, are no other than the *αἰσθητική*, whereby *animalia vivunt et sentiunt*, and the *διανοητική* to which Aristotle ascribes the reasoning faculty of man. Save only that Driesch like Darwin, would deny the restriction of *νοῦς*, or reasoning, to man alone, and would extend it to animals, it is clear, and Driesch himself admits,[2] that he accepts both the vitalism and the analysis of vitalism laid down by Aristotle.

The *πνεῦμα* of Galen, the *vis plastica*, the *vis vitæ formatrix*, of the older physiologist, the *Bildungstrieb* of Blumenbach, the *Lebenskraft* of Paracelsus, Stahl and Treviranus, "shaping the physical forces of the body to its own ends," "dreaming dimly in the grain of the promise of the full corn in the ear,"[3] these and many more, like Driesch's "entelechy" of to-day, are all conceptions under which successive generations strive to depict the something that separates the earthy from the living, the living from the dead. And John Hunter described his conception of it in words not very differentt from Driesch's, when he said that his principle, or agent, was independent of organization, which yet it animates, sustains and repairs; it was the same as Johannes Müller's conception of an innate "unconscious idea."

Even in the middle ages, long before

[2] "Science and Philosophy of the Organism" (Gifford Lectures), II., p. 83, 1908.

[3] *Cit.* Jenkinson (Art. "Vitalism," in *Hibbert Journal*, April, 1911), who has given me the following quotation: "Das Weizenkorn hat allerdings Bewusstsein dessen was in ihm ist und aus ihm werden kann, und traümt wirklich davon. Sein Bewusstsein und seine Träume mögen dunkel genung sein"; Treviranus, "Erscheinungen und Gesetze des organischen Lebens," 1831.

Descartes, we can trace, if we interpret the language and the spirt of the time, an antithesis that, if not identical, is at least parallel to our alternative between vitalistic and mechanical hypotheses. For instance, Father Harper tells us that Suarez maintained, in opposition to St. Thomas, that in generation and development a divine interference is postulated, by reason of the perfection of living beings; in opposition to St. Thomas, who (while invariably making an exception in the case of the human soul) urged that, since the existence of bodily and natural forms consists solely in their union with matter, the ordinary agencies which operate on matter sufficiently account for them.[4]

But in the history of modern science, or of modern physiology, it is of course to Descartes that we trace the origin of our mechanical hypotheses—to Descartes, who, imitating Archimedes, said, "Give me matter and motion, and I will construct the universe." In fact, leaving the more shadowy past alone, we may say that it is since Descartes watched the fountains in the garden, and saw the likeness between their machinery of pumps and pipes and reservoirs to the organs of the circulation of the blood, and since Vaucanson's marvelous automata lent plausibility to the idea of a "living automaton," it is since then that men's minds have been perpetually swayed by one or other of the two conflicting tendencies, either to seek an explanation of the phenomena of living things in physical and mechanical considerations, or to attribute them to unknown and mysterious causes, alien to physics and peculiarly concomitant with life. And some men's temperaments, training, and even avocations, render them more prone to the one side of this unending controvery, as the minds of other men are naturally more open to the other. As Kühne said a few years ago at Cambridge, the physiologists have been found for several generations leaning on the whole to the mechanical or physico-chemical hypothesis, while the zoologists have been very generally on the side of the vitalists.

The very fact that the physiologists were trained in the school of physics, and the fact that the zoologists and botanists relied for so many years upon the vague undefined force of "heredity" as sufficiently accounting for the development of the organism, an intrinsic force whose results could be studied but whose nature seemed remote from possible analysis or explanation, these facts alone go far to illustrate and to justify what Kühne said.

Claude Bernard held that mechanical, physical and chemical forces summed up all with which the physiologist has to deal. Verworn defined physiology as "the chemistry of the proteids"; and I think that another physiologist (but I forget who) has declared that the mystery of life lay hidden in "the chemistry of the enzymes." But of late, as Dr. Haldane showed in his address a couple of years ago to the Physiological Section, it is among the physiologists themselves, together with the embryologists, that we find the strongest indications of a desire to pass beyond the horizon of Descartes, and to avow that physical and chemical methods, the methods of Helmholtz, Ludwig and Claude Bernard, fall short of solving the secrets of physiology. On the other hand, in zoology, resort to the

[4] "Cum formarum naturalium et corporalium esse non consistat nisi in unione ad materiam; ejusdem agentis esse videtur eas producere, cujus est materiam transmutare. Secundo, quia cum hujusmodi formæ non excedant virtutem et ordinem et facultatem principiorum agentium in natura, nulla videtur necessitas eorum originem in principia reducere altiora."—Aquinas, "De Pot.," Q. III., *a*, 11; Cf. Harper, "Metaphysics of the School," III., 1, p. 152.

method of experiment, the discovery, for instance, of the wonderful effects of chemical or even mechanical stimulation in starting the development of the egg, and again the ceaseless search into the minute structure, or so-called mechanism, of the cell, these, I think, have rather tended to sway a certain number of zoologists in the direction of the mechanical hypothesis.

But on the whole, I think it is very manifest that there is abroad on all sides a greater spirit of hesitation and caution than of old, and that the lessons of the philosopher have had their influence on our minds. We realize that the problem of development is far harder than we had begun to let ourselves suppose: that the problems of organogeny and phylogeny (as well as those of physiology) are not comparatively simple and well-nigh solved, but are of the most formidable complexity. And we would, most of us, confess, with the learned author of "The Cell in Development and Inheritance," "that we are utterly ignorant of the manner in which the substance of the germ-cell can so respond to the influence of the environment as to call forth an adaptive variation; and again, that the gulf between the lowest forms of life and the inorganic world is as wide as, if not wider than, it seemed a couple of generations ago."[5]

While we keep an open mind on this question of vitalism, or while we lean as so many of us now do, or or even cling with a great yearning, to the belief that something other than the physical forces animates and sustains the dust of which we are made, it is rather the business of the philosopher than of the biologist, or of the biologist only when he has served his humble and severe apprenticeship to philosophy, to deal with the ultimate problem. It is the plain bounden duty of the biologist to pursue his course, unprejudiced by vitalistic hypotheses, along the road of observation and experiment, according to the accepted discipline of the natural and physical sciences; indeed, I might perhaps better say the physical sciences alone, for it is already a breach of their discipline to invoke, until we feel we absolutely must, that shadowy force of "heredity," to which, as I have already said, biologists have been accustomed to ascribe so much. In other words, it is an elementary scientific duty, it is a rule that Kant himself laid down,[6] that we should explain, just as far as we possibly can, all that is capable of such explanation, in the light of the properties of matter and of the forms of energy with which we are already acquainted.

It is of the essence of physiological science to investigate the manifestations of energy in the body, and to refer them, for instance, to the domains of heat, electricity or chemical activity. By this means a vast number of phenomena, of chemical and other actions of the body, have been relegated to the domain of physical science and withdrawn from the mystery that still attends on life: and by this means, continued for generations, the physiologists, or certain of them, now tell us that we begin again to descry the limitations of physical inquiry, and the region where a very different hypothesis insists on thrusting itself in. But the morphologist has not gone nearly so far as the physiologist in the use of physical methods. He sees so great a gulf between the crystal and the cell, that the very fact of the physicist and the mathematician being able to explain the form of the one, by simple laws of spatial arrangement where molecule fits into molecule, seems to deter, rather than to attract, the biologist from attempting to explain organic forms by mathematical or physical

[5] Wilson, *op. cit.*, 1906, p. 434.

[6] In his "Critique of Teleological Judgment."

law. Just as the embryologist used to explain everything by heredity, so the morphologist is still inclined to say, "the thing is alive, its form is an attribute of itself, and the physical forces do not apply." If he does not go so far as this, he is still apt to take it for granted that the physical forces can only to a small and even insignificant extent blend with the intrinsic organic forces in producing the resultant form. Herein lies our question in a nutshell. Has the morphologist yet sufficiently studied the forms, external and internal, of organisms, in the light of the properties of matter, of the energies that are associated with it, and of the forces by which the actions of these energies may be interpreted and described? Has the biologist, in short, fully recognized that there is a borderland not only between physiology and physics, but between morphology and physics, and that the physicist may, and must, be his guide and teacher in many matters regarding organic form?

Now this is by no means a new subject, for such men as Berthold and Errera, Rhumbler and Dreyer, Bütschli and Verworn, Driesch and Roux, have already dealt or deal with it. But on the whole it seems to me that the subject has attracted too little attention, and that it is well worth our while to think of it to-day.

The first point, then, that I wish to make in this connection is, that the form of any portion of matter, whether it be living or dead, its form and the changes of form that are apparent in its movements and in its growth, may in all cases alike be described as due to the action of force. In short, the form of an object is a "diagram of forces"—in this sense at least, that from it we can judge of or deduce the forces that are acting or have acted upon it; in this strict and particular sense, it is a diagram: in the case of a solid, of the forces that *have* been impressed upon it when its conformation was produced, together with those that enable it to retain its conformation; in the case of a liquid (or of a gas), of the forces that are for the moment acting on it to restrain or balance its own inherent mobility. In an organism, great or small, it is not merely the nature of the *motions* of the living substance that we must interpret in terms of force (according to kinetics), but also the *conformation* of the organism itself, whose permanence or equilibrium is explained by the interaction or balance of forces, as described in statics.

If we look at the living cell of an *Amœba* or a *Spirogyra*, we see a something which exhibits certain active movements, and a certain fluctuating, or more or less lasting, form; and its form at a given moment, just like its motions, is to be investigated by the help of physical methods, and explained by the invocation of the mathematical conception of force.

Now the state, including the shape or form, of a portion of matter is the resultant of a number of forces, which represent or symbolize the manifestations of various kinds of energy; and it is obvious, accordingly, that a great part of physical science must be understood or taken for granted as the necessary preliminary to the discussion on which we are engaged.

I am not going to attempt to deal with, or even to enumerate, all the physical forces or the properties of matter with which the pursuit of this subject would oblige us to deal—with gravity, pressure, cohesion, friction, viscosity, elasticity, diffusion and all the rest of the physical factors that have a bearing on our problem. I propose only to take one or two illustrations from the subject of *surface-tension*, which subject has already so largely engaged the attention of the physiologists. Nor will I even attempt to sketch the gen-

eral nature of this phenomenon, but will only state (as I fear for my purpose I must) a few of its physical manifestations or laws. Of these the most esential facts for us are as follows: Surface-tension is manifested only in fluid or semi-fluid bodies, only at the surface of these: though we may have to interpret surface in a liberal sense in cases where the interior of the mass is other than homogeneous. Secondly, a fluid may, according to the nature of the substance with which it is in contact, or (more strictly speaking) according to the distribution of energy in the system to which it belongs, tend either to spread itself out in a film, or, conversely, to contract into a drop, striving in the latter case to reduce its surface to a minimal area. Thirdly, when three substances are in contact (and subject to surface-tension), as when water surrounds a drop of protoplasm in contact with a solid, then at any and every point of contact, certain definite angles of equilibrium are set up and maintained between the three bodies, which angles are proportionate to the magnitudes of the surface-tensions existing between the three. Fourthly, a fluid film can only remain in equilibrium when its curvature is everywhere constant. Fifthly, the only surfaces of revolution which meet this condition are six in number, of which the plane, the sphere, the cylinder and the so-called unduloid and catenoid are the most important. Sixthly, the cylinder can not remain in free equilibrium if prolonged beyond a length equal to its own circumference, but, passing through the unduloid, tends to break up into spheres: though this limitation may be counteracted or relaxed, for instance, by viscosity. Finally, we have the curious fact that, in a complex system of films, such as a homogeneous froth of bubbles, three partition-walls and no more always meet at a crest, at equal angles, as, for instance, in the very simple case of a layer of uniform hexagonal cells; and (in a solid system) the crests, which may be straight or curved, always meet, also at equal angles, four by four, in a common point. From these physical facts, or laws, the morphologist, as well as the physiologist, may draw important consequences.

It was Hofmeister who first showed, more than forty years ago, that when any drop of protoplasm, either over all its surface or at some free end (as at the tip of the pseudopodium of an *Amœba*), is seen to "round itself off," that is not the effect of physiological or vital contractility, but is a simple consequence of surface-tension—of the law of the minimal surface; and in the physiological side, Engelmann, Bütschli and others have gone far in their development of the idea.

It was Plateau, I think, who first showed that the myriad sticky drops or beads upon the weft of a spider's web, their form, their size, their distance apart, and the presence of the tiny intermediate drops between, were in every detail explicable as the result of surface-tension, through the law of minimal surface and through the corollary to it which defines the limits of stability of the cylinder; and, accordingly, that with their production, the will or effort or intelligence of the spider had nothing to do. The beaded form of a long, thin pseudopodium, for instance of a Heliozoan, is an identical phenomenon.

It was Errera who first conceived the idea that not only the naked surface of the cell but the contiguous surfaces of two naked cells, or the delicate incipient cell-membrane or cell-wall between, might be regarded as a weightless film, whose position and form were assumed in obedience to surface-tension. And it was he who first showed that the symmetrical forms of the unicellular and simple multicellular organ-

isms, up to the point where the development of a skeleton complicates the case, were one and all identical with the plane, sphere, cylinder, unduloid and catenoid, or with combinations of these.

It was Berthold and Errera who, almost simultaneously, showed (the former in far the greater detail) that in a plant each new cell-partition follows the law of minimal surface, and tends (according to another law which I have not particularized) to set itself at right angles to the preceding solidified wall: so giving a simple and adequate physical explanation of what Sachs had stated as an empirical morphological rule. And Berthold further showed how, when the cell-partition was curved, its precise curvature as well as its position was in accordance with physical law.

There are a vast number of other things that we can satisfactorily explain on the same principle and by the same laws. The beautiful catenary curve of the edge of the pseudopodium, as it creeps up its axial rod in a Heliozoan or a Radiolarian, the hexagonal mesh of bubbles, or vacuoles, on the surface of the same creatures, the form of the little groove that runs round the waist of a Peridinian, even (as I believe) the existence, form and undulatory movements of the undulatory membrane of a Trypanosome, or of that around the tail of the spermatozoon of a newt—every one of these, I declare, is a case where the resultant form can be well explained by, and can not possibly be understood without, the phenomenon of surface-tension: indeed, in many of the simpler case the facts are so well explained by surface-tension that it is difficult to find place for a conflicting, much less an overriding, force.

I believe, for my own part, that even the beautiful and varied forms of the Foraminifera may be ascribed to the same cause; but here the problem is just a little more complex, by reason of the successive consolidations of the shell. Suppose the first cell or chamber to be formed, assuming its globular shape in obedience to our law, and then to secrete its calcareous envelope. The new growing bud of protoplasm, accumulating outside the shell, will, in strict accordance with the surface-tensions concerned, either fail to "wet" or to adhere to the first-formed shell, and will so detach itself as a unicellular individual (*Orbulina*); or else it will flow over a less or greater part of the original shell, until its free surface meets it at the required angle of equilibrium. Then, according to this angle, the second chamber may happen to be all but detached (*Globigerina*), or, with all intermediate degrees, may very nearly wholly enwrap the first. Take any specific angle of contact, and presume the same conditions to be maintained, and therefore the same angle to be repeated, as each successive chamber follows on the one before; and you will thereby build up regular forms, spiral or alternate, that correspond with marvelous accuracy to the actual forms of the Foraminifera. And this case is all the more interesting because the allied and successive forms so obtained differ only in degree, in the magnitude of a single physical or mathematical factor; in other words, we get not only individual phenomena, but lines of apparent *orthogenesis*, that seem explicable by physical laws, and attributable to the continuity between successive states in the continuous or gradual variation of a physical condition. The resemblance between allied and related forms, as Hartmann demonstrated and Giard admitted years ago, is not always, however often, to be explained by common descent and parentage.[7]

In the segmenting egg we have the sim-

[7] Cf. Giard, "Discours inaugurale," *Bull. Scientif.* (3), 1, 1888.

pler phenomenon of a "laminar system," uncomplicated by the presence of a solid framework; and here, in the earliest stages of segmentation, it is easy to see the correspondence of the planes of division with what the laws of surface-tension demand. For instance, it is not the case (though the elementary books often represent it so) that when the totally segmenting egg has divided into four segments, the four partition walls ever remain in contact at a single point; the arrangement would be unstable, and the position untenable. But the laws of surface-tension are at once seen to be obeyed, when we recognize the little *cross-furrow* that separates the blastomeres, two and two, leaving in each case three only to meet at a point in our diagram, which point is in reality a section of a ridge or crest.

Very few have tried, and one or two (I know) have tried and not succeeded, to trace the action and the effects of surface-tension in the case of a highly complicated, multi-segemented egg. But it is not surprising if the difficulties which such a case presents appear to be formidable. Even the conformation of the interior of a soap-froth, though absolutely conditioned by surface-tension, presents great difficulties, and it was only in the last years of Lord Kelvin's life that he showed all previous workers to have been in error regarding the form of the interior cells.

But what, for us, does all this amount to? It at least suggests the possibility of so far supporting the observed facts of organic form on mathematical principles, as to bring morphology within or very near to Kant's demand that a true natural science should be justified by its relation to mathematics.[8] But if we were to carry these principles further and to succeed in proving them applicable in detail, even to the showing that the manifold segmentation of the egg was but an exquisite froth, would it wholly revolutionize our biological ideas? It would greatly modify some of them, and some of the most cherished ideas of the majority of embryologists; but I think that the way is already paved for some such modification. When Loeb and others have shown us that half, or even a small portion of an egg, or a single one of its many blastomeres, can give rise to an entire embryo, and that in some cases *any* part of the ovum can originate *any* part of the organism, surely our eyes are turned to the *energies* inherent in the matter of the egg (not to speak of a presiding entelechy), and away from its original formal operations of division. Sedgwick has told us for many years that we look too much to the individuality of the individual cell, and that the organism, at least in the embryonic body, is a continuous syncytium. Hofmeister and Sachs have repeatedly told us that in the plant, the growth of the mass, the growth of the organ, is the primary fact; and De Bary has summed up the matter in his aphorism, "Die Pflanze bildet Zellen, nicht die Zelle bildet Pflanzen." And in many other ways, as many of you are well aware, the extreme position of the cell-theory, that the cells are the ultimate individuals and that the organism is but a colony of quasi-independent cells, has of late years been called in question.

There are no problems connected with morphology that appeal so closely to my mind, or to my temperament, as those that are related to mechanical considerations, to mathematical laws, or to physical and chemical processes.

I love to think of the logarithmic spiral

[8] "Ich behaupte aber dass in jeder besonderen Naturlehre nur so viel *eigentliche* Wissenschaft angetroffen werden könne, als darin Mathematik anzutreffen ist."—Kant, in preface to "Metaphys. Anfangsgründe der Naturwissenschaft" (Werke, ed. Hartenstein, Vol. IV., p. 360).

that is engraven over the grave of that great anatomist, John Goodsir (as it was over that of the greatest of the Bernouillis), so graven because it interprets the form of every molluscan shell, of tusk and horn and claw and many another organic form besides. I like to dwell upon those lines of mechanical stress and strain in a bone that give it its strength where strength is required, that Hermann Meyer and J. Wolff described, and on which Roux has bestowed some of his most thoughtful work; or on the "stream-lines" in the bodily form of fish or bird, from which the naval architect and the aviator have learned so much. I admire that old paper of Peter Harting's in which he paved the way for investigation of the origin of spicules, and of all the questions of crystallization or pseudo-crystallization in presence of colloids, on which subject Lehmann has written his recent and beautiful book. I sympathize with the efforts of Henking, Rhumbler, Hartog, Gallardo, Leduc and others to explain on physical lines the phenomena of nuclear division. And, as I have said to-day, I believe that the forces of surface-tension, elasticity and pressure are adequate to account for a great multitude of the simpler phenomena, and the permutations and combinations thereof, that are illustrated in organic form.

I should gladly and easily have spent all my time this morning in dealing with these questions alone. But I was loath to do so, lest I should seem to overrate their importance, and to appear to you as an advocate of a purely mechanical biology.

I believe all these phenomena to have been unduly neglected, and to call for more attention than they have received. But I know well that though we push such explanations to the uttermost, and learn much in the so doing, they will not touch the heart of the great problems that lie deeper than the physical plane. Over the ultimate problems and causes of vitality, over what is implied in the organization of the living organism, we shall be left wondering still.

To a man of letters and the world like Addison, it came as a sort of revelation that light and color were not objective things but subjective, and that back of them lay only motion or vibration, some simple activity. And when he wrote his essay on these startling discoveries, he found for it, from Ovid, a motto well worth bearing in mind, *causa latet, vis est notissima.* We may with advantage recollect it, when we seek and find the force that produces a direct effect, but stand in utter perplexity before the manifold and transcendent meanings of that great word "cause."

The similarity between organic forms and those that physical agencies are competent to produce still leads some men, such as Stéphane Leduc, to doubt or to deny that there is any gulf between, and to hold that spontaneous generation or the artificial creation of the living is but a footstep away. Others, like Delage and many more, see in the contents of the cell only a complicated chemistry, and in variation only a change in the nature and arrangement of the chemical constituents; they either cling to a belief in "heredity," or (like Delage himself) replace it more or less completely by the effects of functional use and by chemical stimulation from without and from within. Yet others, like Felix Auerbach, still holding to a physical or quasi-physical theory of life, believe that in the living body the dissipation of energy is controlled by a guiding principle, as though by Clerk Maxwell's demons; that for the living the law of entropy is thereby reversed; and that life itself is that which has been evolved to counteract and battle

with the dissipation of energy. Berthold, who first demonstrated the obedience to physical laws in the fundamental phenomena of the dividing cell or segmenting egg, recognizes, almost in the words of John Hunter, a quality in the living protoplasm, *sui generis,* whereby its maintenance, increase and reproduction are achieved. Driesch, who began as a "mechanist," now, as we have seen, harks back straight to Aristotle, to a twin or triple doctrine of the soul. And Bergson, rising into heights of metaphysics where the biologist, *quâ* biologist, can not climb, tells us (like Duran) that life transcends teleology, that the conceptions of mechanism and finality fail to satisfy, and that only "in the absolute do we live and move and have our being."

We end but a little way from where we began.

With all the growth of knowledge, with all the help of all the sciences impinging on our own, it is yet manifest, I think, that the biologists of to-day are in no self-satisfied and exultant mood. The reasons and the reasoning that contented a past generation call for reinquiry, and out of the old solutions new questions emerge; and the ultimate problems are as inscrutable as of old. That which, above all things, we would explain baffles explanation; and that the living organism is a living organism tends to reassert itself as the biologist's fundamental conception and fact. Nor will even this concept serve us and suffice us when we approach the problems of consciousness and intelligence and the mystery of the reasoning soul; for these things are not for the biologist at all, but constitute the psychologist's scientific domain.

In wonderment, says Aristotle, does philosophy begin,[9] and more than once he rings the changes on the theme. Now, as in the beginning, wonderment and admiration are the portion of the biologist, as of all those who contemplate the heavens and the earth, the sea, and all that in them is.

And if wonderment springs, as again Aristotle tells us, from ignorance of the causes of things, it does not cease when we have traced and discovered the proximate causes, the physical causes, the efficient causes of our phenomena. For beyond and remote from physical causation lies the end, the final cause of the philosopher, the reason why, in the which are hidden the problems of organic harmony and autonomy and the mysteries of apparent purpose, adaptation, fitness and design. Here, in the region of teleology, the plain rationalism that guided us through the physical facts and causes begins to disappoint us, and intuition, which is of close kin to faith, begins to make herself heard.

And so it is that, as in wonderment does all philosophy begin, so in amazement does Plato tell us that all our philosophy comes to an end.[10] Ever and anon, in presence of the *magnalia naturæ,* we feel inclined to say with the poet:

οὐ γάρ τι νῦν γε κἀχθὲς, ἀλλ' ἀεί ποτε
ζῇ ταῦτα κοὐδεὶς οἶδεν ἐξ ὅτου 'φάνη.

"These things are not of to-day nor yesterday, but evermore, and no man knoweth whence they came."

I will not quote the noblest words of all that come into my mind; but only the lesser language of another of the greatest of the Greeks: "The ways of His thoughts are as paths in a wood thick with leaves, and one seeth through them but a little way."

D'ARCY WENTWORTH THOMPSON

PROSPECTIVE POPULATION OF THE UNITED STATES

VARIOUS estimates of the probable or possible future population of the United States

[9] "Met.," I., 2, 982*b*, 12, etc.

[10] Cf. Coleridge, "Biogr. Lit."

have been made, chiefly on the basis of extrapolation from figures of past growth in comparison with past and present population of other countries, and generally on the assumption that the sources of life and habitability are either unlimited or limited only by land area. One of the latest and most comprehensive estimates is that of Henry Gannett, geographer of the tenth, eleventh and twelfth censuses;[1] it was made without reference to limitation of sources of life, but in the light of the decreasing percentage increment of population shown by records of this and other countries. His figures for prospective increase are essentially arbitrary, decreasing from 21 per cent. during the decade 1900–1910[2] to 5 per cent. for the decade 2090–2100, giving populations of 90,000,000 in 1910, about 250,000,000 in 2000 and 500,000,000 a century later. Thus far no comprehensive extrapolations based on the thirteenth census appear to have been made.

Recent researches tend to indicate that the assumption of unlimited resources, or of resources limited only by land area, is unwarranted; for while the mineral resources of the United States are vast, while the forests are renewable and the farms susceptible of large increase in productivity, while the atmosphere gives little threat of exhaustion (despite the gloomy anticipations of Sir William Crookes and others concerning the stock of nitrogen), and while the available sun-power is thus far used to but a small fraction of its capacity, a practical limit to the productivity and habitability of the country is fixed by limitation in the water supply—and it is worth while to consider prospective population in the light of this limitation.

Standards for the use of water in relation to crop production and the maintenance of human existence arise under irrigation in arid regions, where water is measured more carefully and balanced more exactly against plant and animal life than in humid lands. Here 25 acre-feet of water properly used in agriculture or horticulture will sustain a family of five for a year, with the requisite surplus production for exchange; the best results follow application of the water on five acres of land to an aggregate of five feet in depth as needed during the season. Using water in this way, the rural population is one per acre, or 640 per square mile, stated in terms of land; but it is justly measured only as one for each 5 acre-feet (6,800 tons) of that menstruum which alone renders land productive.

The standards fixed in arid regions are not greatly different from those arising of late in humid lands. Hellriegel in Germany and King in this country have shown that crop plants require for their growth a quantity of water, measured by transpiration, averaging from 300 to 600 (with a mean of about 450) times the weight of the plants after drying; and common field experience indicates that in addition to the moisture passing through the plants the soil requires an even larger quantity to maintain a texture suitable for crop growth —much of which passes away through evaporation and seepage. On this basis "the agricultural duty of water" in this country has been formulated as *the production of one-thousandth part of its weight in average plant crop.*[3] Reckoning human food and drink on this basis, and assuming that meats require (chiefly in the growth of plants used as feed for the animals) ten times the quantity of water represented in vegetal food, it appears that the adult who eats 200 pounds each of bread and beef in a year consumes something like a ton of water in drink and the equivalents of 400 tons in bread and 4,000 tons in meat, or 4,401 tons in all—figures corresponding fairly with the results of intensive agriculture in arid districts. Accordingly, the

[1] Report of the National Conservation Commission (Sixtieth Congress, Second Session, Senate Document 676), 1909, Vol. 2, pp. 7–9.

[2] Perhaps through misprint, Gannett's increment for this decade does not correspond with the population figures; it is put at 21 per cent.—the rate subsequently determined by the Thirteenth Census —though his estimate of 90,000,000 is only 19.2 per cent. above the 75,569,000 (or 18.4 per cent. above the 76,000,000) appearing in his tables.

[3] "Yearbook of the Department of Agriculture," 1910, pp. 169–176; Bureau of Soils Bulletin 71, 1911, pp. 7–14.

"duty of water" considered in relation to human population may be stated roughly as *the maintenance of a human life a year for each 5 acre-feet used effectively in agriculture.*

Now mainland United States (*i. e.*, the chief body of our territory, exclusive of Alaska and the insular possessions) comprises something over 3,000,000 square miles, or somewhat less than 2,000,000,000 acres of land; yet the annual rainfall—the sole original source of fresh water—averages barely $2\frac{1}{2}$ feet (30 inches), or hardly 5,000,000,000 acre-feet. So while the land area, if peopled to the density of Belgium (over 640 per square mile), would carry a population of 2,000,000,000, the water supply suffices for only 1,000,000,000.

Of course all these figures are but approximations; yet they indicate that the method of measuring capacity for population in terms of land area is adapted only to countries in which the water supply is ample, and that in this and most other countries estimates can safely be based only on the quantity of water available for the production of those staples of life used in food and clothing. Water is indeed the primary resource. In plant life it is essential to germination, to tissue-making, to all growth; and far the greater part of the average growing plant consists of water, chiefly in circulation. For men and other animals water is the leading food; the average human ration is some 6 pounds daily, $4\frac{1}{2}$ liquid and $1\frac{1}{2}$ nominally solid, but actually more than one third water—*i. e.*, fully five sixths of the sustenance (and indeed a like proportion of the bodies) of human beings is water. Within the body there is no assimilation or metabolism in the absence of water, nor does germination or any other vital process take place without it or apparently otherwise than as a manifestation of its inherent properties. The measure of water is the measure not merely of productivity but of vitality; and disregarding other climatal factors, the habitability of every country on the globe is determined by the presence or absence, and finally by the quantity, of water distilled from the oceans, circulating through the atmosphere, and descending on the land.

Considered in relation to natural water supply, mainland United States comprises three divisions: (1) the humid section, or eastward states—31 in number—extending from the Minnesota-Louisiana tier to the Atlantic, commonly viewed as the chief part of the country though forming only two fifths of its area; (2) the sub-humid section, or 6 median states from the Dakotas to Texas, containing a fifth of the area of the country; and (3) the semi-arid section, or westward states—11 in number, including Arizona and New Mexico—making up the remaining two fifths of the territory.

Over the humid section the mean annual rainfall ranges from about 25 inches in Minnesota to 55 in Mississippi and over 70 in the southern Appalachians, averaging some 48 inches, or four fifths that required for full productivity. In round figures, the 800,000,000 acres receive annually over 3,000,000,000 acre-feet of rainfall, or nearly two thirds of the entire supply of the country, and now sustain a population of 75,000,000. The prospective population, reckoned on the basis of 5 acre-feet of water supply per capita annually, may reach 600,000,000, or 8 times that of the present; so far as may be foreseen, that population could best be sustained by intensive cultivation to such degree that each ten-acre lot would yield materials for food and clothing for a family of five direct producers, and perhaps an equal number of urban residents living by secondary production or incidental industries.

Over the 400,000,000 acres comprised in the median states the rainfall averages scant 30 inches, or half the water required for full productivity (though as shown by Gannett from 60 per cent. to over 80 per cent. of it falls during the six summer months). While adapted only to extensive agriculture, the capacity of this section for production of staples is far beyond the present yield; if the entire water supply (including the natural sub-irrigation from the Rocky Mountains) were effectively used, it would sustain a family to

each 40-acre lot with another living in town or depending on transportation for livelihood; when the aggregate population would reach 200,000,000, or twenty times that of to-day.

Over the 800,000,000 acres of the westward states the rainfall ranges from less than 2 to over 100 and averages about 12 inches, aggregating some 800,000,000 acre-feet yearly, or a fifth of the productivity standard. The entire water supply would suffice for the intensive cultivation of only 160,000,000 acres; but the present and prospective utilization is highly efficient (the "return water" from irrigation is used over and over again), so that the possible population may be estimated at 200,000,000, or thirty times that of to-day.

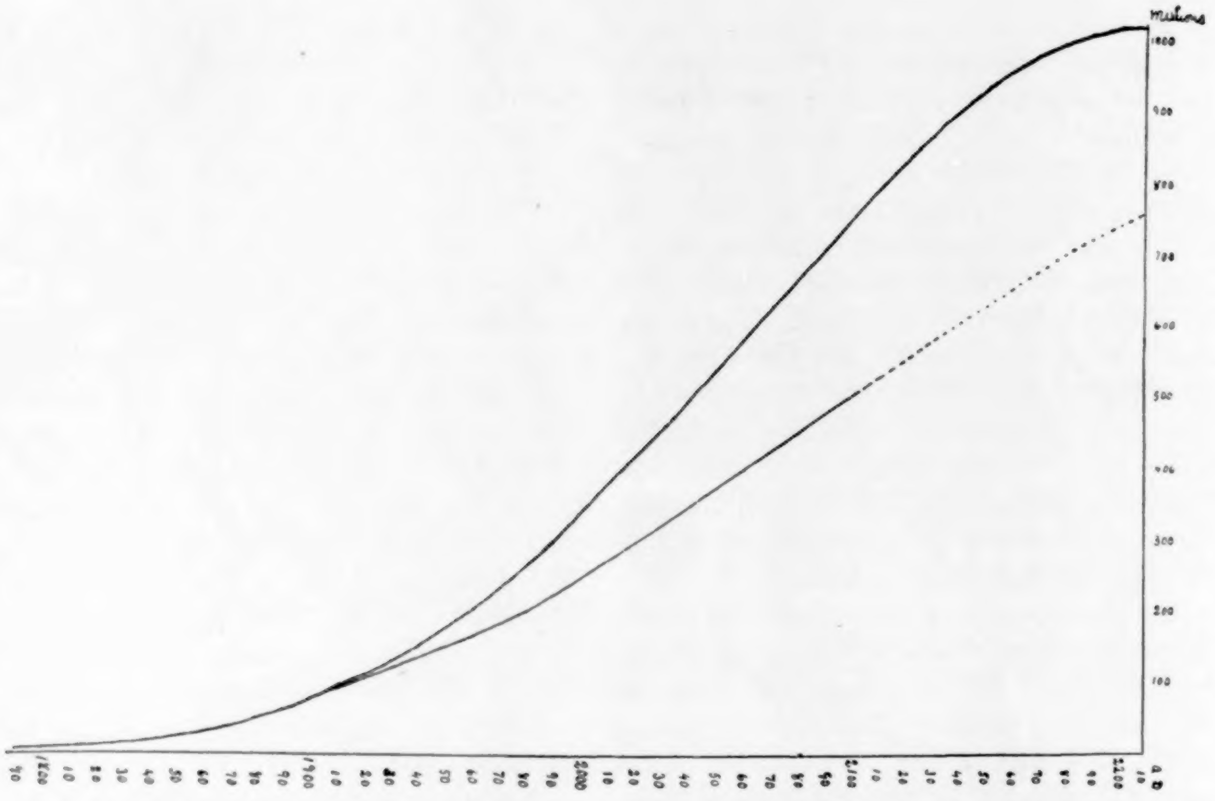
These estimated populations are comparable with present populations in several countries. The 600,000,000 for the eastward states is about one fifth greater than that of China (438,214,000) and Japan (50,751,919) combined; the density is 500 per square mile, almost exactly that of Lombardy (495), little above that of the Netherlands (467), only 1⅓ times that of the United Kingdom (372), little more than three fourths that of Belgium (649), two thirds that of Saxony (778) and half that of (settled) Egypt (931). The 200,000,000 for the median states is considerably less than the population of British India (231,855,583); the density is 333 per square mile, below that of Japan (344) but above that of Alsace-Lorraine (324), Germany (311) and Italy (310), not greatly above that of China (266), and little more than half that of Java (595). The 200,000,000 for the westward states would give a density of 167 per square mile, the same as that of Denmark and Hungary and considerably below that of France (190), Switzerland (234), Bavaria (223), Formosa (226), Austria (246) or Poland (232).[4] The aggregate of 1,000,000,000 for mainland United States is comparable with the present population of Asia or twice that of Europe; the mean density is 333 per square mile, about mid-way between that of the United Kingdom and Germany, little more than half that of Belgium, less than half that of Saxony and only about one third that of Egypt.

The rate of increase in population to the limit fixed by water supply may be extrapolated roughly; and despite the favorable prepossesion due to Gannett's experience (greater perhaps than that of any other census student in the country), his estimate of the decennial increment may be somewhat increased—for several reasons. In the first place his estimate for the 1910 population, although made but a few months in advance of enumeration and in the light of the approximate figures of late prepared in the Census Office, was nearly 2,000,000 too low. Again, the advance during recent years in etiology, sanitation, surgery and other factors of health and viability have virtually given a new lease of life to mankind in this and other countries, while the influence of enlightenment is rapidly spreading, so that (in spite of a declining birth-rate) the population of the world generally appears to be increasing at an unprecedented rate. Furthermore, in this country primary production (*i. e.,* of foodstuffs and textiles) has within a few years past increased with unparalleled rapidity, perhaps more rapidly than manufacturing or transportation in their palmiest days; taking the value of the farm products of 1899 at 100 as a basis, the relative value for 1905 was 133; for 1906, 143.4; for 1907, 158.7; for 1908, 167.3; for 1909, 182.8, and for 1910, 189.2—the absolute value for this last year reaching $8,926,000,000.[5] Meantime the influx of prolific immigrants continues, and a large proportion of them are finding their way into rural districts and primary industries where the conditions are favorable to family life. These various considerations warrant the expectation of a vigorous and sustained growth in the population of this country for many years.

It is true that apparent indications of ap-

[4] The figures are taken (the population-density generally computed) from areas and populations in the "Statesman's Yearbook," 1910, supplemented by records for 1910 compiled by Gannett (*Nat. Geog. Mag.,* Vol. XXII., 1911, p. 785).

[5] "Yearbook of the Department of Agriculture," 1910, p. 10.



proaching paralysis have arisen, *e. g.*, in a cost of living exceeding that of any other age or country, in diminishing exports of foodstuffs, etc.; yet it seems probable that these conditions mark a temporary rather than permanent disturbance of economic balance between primary and secondary industries—a disturbance destined to be progressively adjusted, unless current signs of the times be wholly misleading. The primary industries—the production of materials for food and clothing chiefly from the soil through utilization of the natural water supply—dominated the growth of the country from 1776 to about 1850; but especially during the half-century 1850–1900 the secondary industries of manufacturing and transportation expanded beyond all precedent or parallel, until the annual value of manufactures arose to more than twice that of the primary staples, and the cost of transportation increased to a quarter or a third of the value of primary production. Despite this industrial revolution, a reasonable balance was long maintained through rapid agricultural expansion and the bringing of virgin fields under cultivation, whereby the secondary workers were fed and clothed without appreciable burden on the resources of the country. Of late this method of maintaining the economic balance has failed, since the virgin fields available for settlement and cultivation in the old way are exhausted—and the industries of the United States have grown top-heavy in manufacturing and transportation. The burden of manufacturing is the greater by reason of a tariff adapted neither to the raising of revenue nor to the protection of American workmen so much as the concentration of capital; yet indications are clear that within a year this burden will be materially reduced by revision of the tariff laws. The burden of transportation has arisen chiefly with the growth of railways in property and power until the simple economic law of supply and demand has been replaced by the arbitrary formula "what the traffic will bear," which largely controls production; the annual cost of railway transportation (of which some 70 per cent. is freightage) is now about $2,700,-000,000, equivalent to an impost of $5.25 per acre on the 475,000,000 acres of improved land in this country, or a personal tax of $150 per family (fully one third of the average cost of

PAST AND PROSPECTIVE POPULATION OF MAINLAND UNITED STATES

Year A.D.	Present Estimate			Gannett Estimate		
	Population	Increase		Population	Increase	
1790	3,929,214	....	......	3,929,000	....	......
1800	5,308,483	1,379,269	=35.1%	5,308,000	1,379,000	=35 %
1810	7,239,881	1,931,398	36.4	7,240,000	1,931,000	36
1820	9,638,453	2,398,572	33.1	9,638,000	2,399,000	33
1830	12,866,020	3,227,567	33.5	12,866,000	3,228,000	33
1840	17,069,453	4,203,433	32.7	17,069,000	4,203,000	33
1850	23,191,876	6,122,423	35.9	23,192,000	6,122,000	36
1860	31,443,321	8,251,445	35.6	31,443,000	8,251,000	36
1870	38,558,371	7,115,050	22.6	38,558,000	7,115,000	23
1880	50,155,783	11,597,412	30.1	50,156,000	11,597,000	30
1890	62,947,714	12,791,931	25.5	62,622,000	12,466,000	25
1900	75,994,575	13,046,861	20.7	75,569,000	12,946,000	21
1910	91,972,266	15,977,691	21.0	90,000,000		21(?)
1920	110,000,000	18,000,000	20	104,000,000		16
1930	131,000,000	21,000,000	19	119,000,000		14
1940	155,000,000	24,000,000	18	134,000,000		13
1950	181,000,000	26,000,000	17	150,000,000		12
1960	210,000,000	29,000,000	16	167,000,000		10
1970	241,000,000	31,000,000	15	184,000,000		10
1980	275,000,000	34,000,000	14	202,000,000		10
1990	311,000,000	36,000,000	13	225,000,000		11
2000	348,000,000	37,000,000	12	249,000,000		11
2010	386,000,000	38,000,000	11	274,000,000		10
2020	425,000,000	39,000,000	10	299,000,000		9
2030	463,000,000	38,000,000	9	325,000,000		9
2040	505,000,000	42,000,000	9	350,000,000		8
2050	545,000,000	40,000,000	8	375,000,000		7
2060	589,000,000	44,000,000	8	400,000,000		7
2070	630,000,000	41,000,000	7	425,000,000		6
2080	674,000,000	44,000,000	7	450,000,000		6
2090	714,000,000	40,000,000	6	475,000,000		5
2100	757,000,000	43,000,000	6	500,000,000		5
2110	795,000,000	38,600,000	5	*525,000,000*		*5*
2120	835,000,000	40,000,000	5	*551,000,000*		*5*
2130	868,000,000	33,000,000	4	*573,000,000*		*4*
2140	903,000,000	35,000,000	4	*596,000,000*		*4*
2150	930,000,000	27,000,000	3	*620,000,000*		*4*
2160	958,000,000	28,000,000	3	*645,000,000*		*4*
2170	977,000,000	19,000,000	2	*671,000,000*		*4*
2180	997,000,000	20,000,000	2	*691,000,000*		*3*
2190	1,007,000,000	10,000,000	1	*712,000,000*		*3*
2200	1,017,000,000	10,000,000	1	*733,000,000*		*3*
2210	1,017,000,000	0	0	*755,000,000*		*3*

living); but already the railways are passing under regulation in the public interest by the Interstate Commerce Commission, while with that proper development of waterways destined to come before the next decennial census the aggregate cost of freight movement will be reduced 20 per cent. or 30 per cent. So on the whole any apparent paralysis in growth arising in imperfect economic balance would seem to be more apparent than real, and at the worst of temporary character.

The decennial percentage increment of population decreases normally with growth. During the twelve decades covered by the United States census the increments have varied from 36.4 per cent. (1800–1810) to 20.7 per cent. (1890–1900), averaging 30.4 per cent.; the mean for the earlier six being 34.4 per cent. and for the later six 25.9 per cent. The decreases have not been uniform; during the second decade there was a slight increase, during the sixth a decided increase, during the ninth (following the civil war decade) a still greater increase, and during the twelfth a slight increase (from 20.7 per cent. to 21 per cent.).

In the extrapolation based on (1) past growth, (2) current promise of prospective growth and (3) limitation of growth by water supply, it may be assumed that the percentage increment will diminish steadily at the rate of 1 per cent. during each decade for a century, and then more slowly (1 per cent. during each two decades) for two centuries more, when the population limit fixed by water supply may be reached. Reckoned on this assumption, the prospective population is shown in the accompanying table and diagram (the figures from 1790 to 1810 from Census Bulletin 109), in which Gannett's estimates are introduced for comparison, and extended from A.D. 2100 to A.D. 2210 on the basis of percentage increments decreasing conformably with his figures for the two preceding centuries.

It is true that in the era of commercial interchange on which the world has fairly entered no country exists wholly unto itself, but subsists in part on the resources of other lands and in prospectively increasing degree on those of the waters; theoretically, the population-estimate for any country should take account of the capacity of other countries for yielding and exchanging necessaries of life—*i. e.*, the materials for food and clothing; but practically, the cost of exchange (including transportation) imposes a burden directly on the consumers and less directly on the producers of commodities, and if these are prime necessaries this burden tends quickly to become unbearable—when the people on whom it rests must cease increasing and may even decrease until an economic balance is attained. Yet by reason of areal extent and variety of resources, mainland United States is potentially self-contained in exceptional degree (unexcelled natural wealth in materials for manufacturing and the development of power are combined with a large capacity for

producing prime necessaries), so that prognostications of growth in this country are apparently safer than in any other. The very extent of territory contributes to its self-content and isolation; its magnificent distances involve such cost in transportation (and must continue to do so, despite prospective improvement in facilities) as to limit interchange between producing areas and ports, and thus to restrict foreign commerce; every transcontinental traveler must be impressed by the vast tracts in the westward states unproductive and nearly uninhabitable because of aridity, yet few realize that with half its area and the present water supply equably distributed mainland United States could sustain a population equal to its present capacity and maintain freer foreign commerce by reason of the reduced average distance and cost of domestic traffic. The various factors affecting any forecast of future production and population in this country indicate that the growth will be exceptionally independent and presumably uniform. The highest numerical increment in the accompanying tabulated estimate (for a century and a half hence) is 44,000,000 in a decade, only 2¾ times that of the last decade with an estimated population sevenfold greater. The maximum estimated population of about 1,000,000,000 is less than eleven times that of 1910; and any excess in the estimated increments may be balanced by extending the estimated date (about A.D. 2200) a few decades further into the future. By way of comparison it may be noted that since the rainfall on the lands of the globe is some 30,000 cubic miles (or 100,000,000,000 acre-feet), the maximum world population, computed on the same basis, is 20,000,000,000, or about thirteen times the present 1,500,000,000.

Whatever the probability of error in the forecast, it would seem timely to consider the prospective population of this and other countries in the light of the leading lessons of anthropology, (1) that the development of mankind is progressive, (2) that the distinctive attribute of the human realm is mentality and (3) that through cumulatively advancing mentality man (unlike other organisms) adjusts himself to environment in increasing degree by subjugation of lower nature. Accordingly, the capacity for population of any country during any generation depends not merely on the natural resources but on these resources as modified and adapted to human needs by human genius; while the food quest is fundamental, the sources of food (and of clothing as well) for enlightened folk are not the natural fauna and flora but cultivated and virtually artificialized plants and animals; while tools and machines and mechanical power are necessaries of industrial activity, their sources are no longer those found ready-made in nature but are secondary products gained by artificial conversion of natural materials and forces—and no end to this reconstruction of nature is in sight save the limitation to life first in water supply and then in other constituents of atmosphere and earth. Meantime the power and efficiency of humanity are advancing; throughout the world men now meet in amity rather than instinctive enmity as in savagery and barbarism, and while there will yet be bloody battles before warfare is made so sanguinary by mechanical and chemical devices that mankind will revolt against it, the current trend is toward national no less than individual obedience to law and hence toward international peace; famine grows less fatal with advancing solidarity of peoples; pestilence is passing with the advance of science and philanthropy; health and happiness and viability have increased almost uninterruptedly from the prime to the present, and give every promise of continued increase; and most significant of all, the social and governmental institutions of all countries are steadily rising from primitive types in which the lives of the many were at the mercy of a favored few to that plane on which all lives are alike sacred—indeed the modern and prospective governmental form is but the organized expression of the knowledge and opinions and sentiments—*i. e.,* of the essentially human traits—of a constituent citizenry. In the light of past progress, it is the manifest destiny of the temperate and tropical zones to

be subjugated and controlled for human welfare through a continued and cumulative conquest limited only by capacity for yielding necessaries of life. While other limiting factors may arise as mentality extends and intensifies, that most evident to-day in this and several other countries is the water supply; yet even this barrier may not prove insuperable by advancing invention so long as the constituents of water abound in other combinations in the external earth-crust. Whatever the uncertainties, any definite estimate of future population made in the light of limitations arising in current knowledge of resources is more likely to be found too small than too large as knowledge and command over nature advance with the progressive development of mankind.

W J McGEE

THE SILLIMAN LECTURES

THE Silliman lectures for 1911 will, as already announced, be given at Yale University by Professor Max Verworn, of the University of Bonn. They will be given in Lampson Hall at five o'clock on successive days beginning on Monday, October 9. The subjects are as follows:

I. Historical Observations on the Doctrine of Irritability.
II. The Meaning of Stimuli.
III. The Special Characteristics of Stimuli.
IV. The General Effects of Stimulation.
V. The Analysis of Excitation.
VI. The Conductivity of Excitation.
VII. Refractory Period and Fatigue.
VIII. The Interference of Excitation.
IX. The Interference of Excitation. (*Continued.*)
X. The Processes of Depression.

The preceding lectures on the Silliman foundation have been:

1903. Professor Thomson, Cambridge University: Electricity and Matter.
1904. Professor Sherrington, University of Liverpool: Integrative Action of the Nervous System.
1905. Professor Rutherford, McGill University: Radio-active Transformations.
1906. Professor Nernst, University of Berlin: Applications of Thermodynamics to Chemistry.
1907. Professor Bateson, Cambridge University: The Problems of Genetics.
1908. Professor Penck, University of Berlin: The Problems of Glacial Geology.
1909. Professor Campbell, Lick Observatory, University of California: Stellar Motions.
1910. Professor Arrhenius, University of Stockholm: The Theories of Solutions.

SCIENTIFIC NOTES AND NEWS

PROFESSOR W. S. EICHELBERGER, director of the Nautical Almanac, will represent the United States at a conference of the directors of the National Nautical Almanacs to be held at Paris from October 23 to 28.

AT Harvard University Professors W. M. Davis (geology), P. H. Hanus (education), E. V. Huntington (mathematics) and E. B. Holt (psychology) have leave of absence from the university for the academic year 1911–12; Professors Theobald Smith (comparative pathology), George Santayana (philosophy), R. B. Perry (philosophy) and D. W. Johnson (physiography), for the second half-year.

THE Hanbury gold medal of the British Pharmaceutical Society has been awarded to M. Eugene Léger, of the Hôpital St. Louis, Paris.

DR. G. A. HANSEN, president of the permanent international committee on leprosy, was one of the founders of the *Medicinsk Revue* in Norway in 1884. On the occasion of his seventieth birthday recently, as we learn from the *Journal* of the American Medical Association, the *Revue* issued a special *Festschrift* number in his honor with fifteen articles on various topics, especially leprosy and pellagra, all by Norwegian writers.

PROFESSOR CHARLES L. EDWARDS, of the University of Southern California, has been placed in charge of the abalone investigations instituted by the Fish and Game Commission of the state of California.

WE learn from *Nature* that Mr. J. J. Nock has been appointed by the British secretary of

state for the colonies, on the recommendation of the Kew authorities, curator of the Hakgala Gardens, Ceylon.

MR. MARCONI has been elected president of the Junior Institution of Engineers in succession to Sir J. J. Thomson, F.R.S.

M. G. FAYET, of the Paris Observatory, has been appointed astronomer at the Nice Observatory, in succession to M. Simonin.

IT is stated in *Nature* that Dr. R. Karsten, lecturer in comparative religion in the University of Helsingfors, has started on an expedition to Gran Chaco and Bolivia for the purpose of making investigations on the sociology and religion of various tribes of natives, some of whom are little known, while others have never been visited. He will be accompanied by his cousin, O. Lindholm.

A BRONZE statue has been erected at Poleymeux, in the Rhone Department, France, in memory of Ampère.

MR. EDWARD WHYMPER, known for his explorations among the Alps, in the Andes and elsewhere, died at Chamonix on September 16, aged sixty-one years.

DR. LOUIS BRAUNDET, professor of anatomy at the medical school at Reims, has died from anthrax, contracted in the course of his professional duty.

THE Civil Service Commission will hold an examination for assistant forest ranger on October 23–24, 1911. The U. S. Department of Agriculture estimates that 400 eligibles will be needed during the field season of 1912. Assistant forest rangers are paid an entrance salary of $1,100 per annum. The examination will be held at National Forest headquarters in Alaska, Arizona, Arkansas, California, Colorado, Florida, Idaho, Kansas, Minnesota, Montana, Nebraska, Nevada, New Mexico, Oklahoma, Oregon, South Dakota, Utah, Washington and Wyoming. The law requires that, when practicable, forest rangers must be qualified citizens of the state or territory in which the national forest on which they are appointed is situated. Since the list of local eligibles must be exhausted before eligibles residing in other states can be appointed, the chance of citizens of outside states who go to National Forest states and take the examination to secure an appointment is small.

THE eleventh intercollegiate geological excursion will be held on October 13 and 14 in the vicinity of Boston under the direction of Professor A. C. Lane, of Tufts College. The north side of the Boston basin will be visited to study shore changes, salt marsh peat as evidence of subsidence, beach cusps, the gabbro diabase of Nahant and Medford, and the Cambrian contact zone. Further information may be obtained from the secretary, Professor Herdman F. Cleland, Williams College.

AT the last meeting of the Ohio State Archeological and Historical Society, G. F. Wright was elected president; E. O. Randall, secretary, and W. C. Mills, curator. The legislature at its last session, in addition to its ordinary appropriations for field work and general expenses, voted $100,000 for a museum building to be erected on the grounds of the State University at Columbus. also $40,000 for the erection of a fire-proof building in Fremont, Ohio, to preserve the valuable library of Americana and political documents left by the late President Hayes. This also secures to the state, for a public park, the grounds, to the extent of twenty-five acres, surrounding the homestead of ex-President Hayes.

THE meeting of the International Sanitary Conference to revise the provisions of the convention of 1903 for the prevention of the invasion and propagation of plague and cholera, is to take place in Paris on October 10 next.

FIFTY thousand dollars will be sought of congress by the Public Health and Marine Hospital Service for the suppression of pellagra. The annual report of Surgeon-General Wyman, soon to appear, will show the great strides that have been made by the disease in the last two years. It is said that it is increasing annually more than 100 per cent. It is said that there are in the south more than 10,300 cases.

WE learn from *Nature* that an agreement has been signed by the representatives of the

United Kingdom and Germany, the carrying into effect of which will mean a thorough investigation into the extent of sleeping sickness in the Gold Coast Colony, the Ashanti and northern Territory Protectorates, and Togoland. Each government will keep the other informed of the incidence, extent and possible spread of the disease in its territory, and will treat the other's native subjects free of charge; but each may impose restrictions on the frontier traffic and may prevent suspected sufferers from crossing its border. The agreement is for three years certain from December 1, 1911, and continues thereafter for yearly periods, unless denounced at least six months before the close of a year.

A REPORT on the geology of the Lake Superior region, by President C. R. Van Hise and Professor C. K. Leith, of the University of Wisconsin, has been published by the United States Geological Survey as Monograph 52. This monograph represents the survey's first attempt to cover the geology of the region in a single volume and forms at once a notable contribution to the literature of American geology and a guide book for the exploitation of the mineral wealth of the region. It covers 641 pages and contains chapters on all the iron and copper producing districts as well as full descriptions of the iron and copper ores. It includes accurate maps of all the districts and a general geologic map of the region. The illustrations number 49 plates and 76 text figures, comprising maps, sections, diagrams and halftone reproductions of photographs of ores and minerals.

A CIRCULAR, quoted in *Nature,* respecting the work of the Aberdeen University Bird-migration Inquiry has been issued by Professor J. Arthur Thomson and Mr. A. L. Thomson. The object of the movement is the collection of more definite information on migration by the method of placing aluminium rings on the feet of a large number of birds, in the hope of hearing of the subsequent movements of some proportion of the birds. The rings are inscribed with the address "Aberdeen University," and a number (or number and letter combination) different in each case. The rings are placed on young birds found in the nest, or on any old ones that can be captured without injury. The following extracts are taken from the circular above-mentioned: (1) "It is particularly requested that all who may shoot, capture or kill or even hear of any of our marked birds, should let us know of the occurrence. As accurate particulars of date and locality as possible are desired, but, above all, the number (or number and letters) on the ring. Indeed, except where it has been possible to reliberate the bird uninjured, the ring itself should always be sent, or the ring and foot, or even the whole bird. We always refund postage if asked to do so." (2) "We invite the cooperation in the actual work of marking of any who are specially interested, and have some knowledge of birds and also time and opportunity for the work. The necessary rings, schedules, postage stamps, etc., are supplied by us, without charge, and we undertake to let the marker know of each case of a bird marked by him being recovered, and to let him have copies of printed reports as far as possible."

A SERIES of analyses of the water of the Mississippi River made by chemists of the United States Geological Survey, reveals the changes in its character at different points. At Minneapolis the water of the Mississippi is very simple in character, being distinguished only by secondary alkalinity, primary salinity and very low secondary salinity or permanent hardness. At Moline, Ill., permanent hardness appears definitely among the properties of the Mississippi water, although it occupies a very subordinate position. At Chester, Ill., however, the character of the water appears to be greatly changed, for the analyses indicate that the proportion of primary salinity is much increased and the proportion of permanent hardness is more than doubled. This change is due to the highly saline waters received from the Missouri at a point between Quincy and Chester. From Chester to New Orleans the river water appears to undergo no permanent change in gen-

eral character. Additional contributions of saline waters from the west, received through Arkansas and Red rivers, suffice to maintain in the water of the lower Mississippi that high proportion of salinity first derived midway in its course from the Missouri River.

West of Koyukuk and Yukon rivers in Alaska a large area has long remained geologically unexplored. In a portion of this region an exploration party from the United States Geological Survey worked during the season of 1909, and the results of the studies there carried on and extended as far as Council, in Seward Peninsula, are set forth in Bulletin No. 449 just issued by the survey. The party consisted of Philip S. Smith and H. M. Eakin, geologists of the survey and authors of the report, A. G. Winegarden, packer, and a cook. Supplies for a month were shipped to Nulato, the point from which the expedition set out, and other supplies, sufficient to last the rest of the season, were sent to Nome and then transported to the mouth of the Koyuk and there cached to await the arrival of the party. The area traversed by this party was selected for survey because it was thought that the metamorphic rocks of the Seward Peninsula might occur within it, which would give presumption of the presence of gold deposits. In addition to exploring the region east of Norton Bay the party carried the topographic and geologic mapping into the southeastern part of the Seward Peninsula, thus extending the areas mapped by the Geological Survey in earlier years. The report is a volume of 140 pages, describing the topography and geology of the area and containing notes on its climate, vegetation, game and fish. Some 40 pages are devoted to the mineral resources—placer and lode gold deposits and prospects, and silver, lead, copper and coal. It is illustrated with photographs and brief sketch maps and contains also a topographic reconnaissance map of southeastern Seward Peninsula, on the scale of four miles to the inch, a colored geologic map of the same area and a colored geologic map of Nulato-Norton Bay region, on the scale of 8 miles to the inch.

Fluorspar, one of the lesser minerals, has come to occupy a comparatively important place in every-day affairs. It is used in the manufacture of glass, of enameled and sanitary ware, in refining antimony and lead, in the production of aluminum, and as a flux in blast furnaces and in the manufacture of steel in basic open-hearth furnaces. The production of open-hearth steel alone in 1910 was over 15,000,000 long tons. The production of fluorspar, according to Ernest F. Burchard, of the United States Geological Survey, in a report on fluorspar and cryolite just issued, increased from 18,450 short tons in 1900, valued at $94,500, to 69,427 tons in 1910, valued at $430,196. There was an increase in 1910 of 37 per cent. in quantity and 47 per cent. in value over the figures for 1909. The deposits which have been exploited are in Arizona, New Mexico, Colorado, Illinois, Kentucky, Tennessee and New Hampshire. Illinois is much the heaviest producer. There was also imported in 1910, according to Mr. Burchard, 42,488 short tons, valued at $135,152. Mr. Burchard's report contains, in addition to the statistics of the industry, a discussion of the methods of mining and milling fluorspar as well as a description of recently discovered high-grade deposits in New Mexico.

A volume containing the reports for the year 1909–10 from those universities and university colleges in Great Britain which participate in the parliamentary grant has been issued as a blue-book and an abstract is given in the London *Times*. The introductory report of the Board of Education, which is signed by Mr. Runciman, Mr. Trevelyan and Sir Robert Morant, deplores the fact that, apart from the recent munificent gifts to Reading University College, the endowments provided by private benefaction during the period have not been comparable in magnitude and importance with those of the late Sir Alfred Jones, Mr. Otto Beit, M. Albert Kahn or Mr. W. H. Lever, to which reference was made in the last report, although there probably was never a time when university education was in greater need of encouragement. The apathy of the public at large is

only too frequently reflected in the attitude of local authorities, some of the most important of whom give far less than their proper share of support to the universities, and in one or two instances the maintenance at their present level of the grants made by local education authorities has been endangered. For the financial year 1909–10 the amount of grant actually paid by the treasury to university colleges in England was £96,100, and for the year 1910–11 £101,250. In the year 1909–10 £15,000 was added to the grant in aid of university education in Wales. Dealing with the problem of university education in the metropolis, the introductory report dwells on the need for a proper scheme of coordination, which it holds to be especially urgent in the case of higher technological and professional work, and declares that until the problem has been adequately dealt with it is almost impossible to deal wisely with even the most urgent claims for further development. With regard to finance, the report shows that nearly 33 per cent. of the income of English colleges is derived from fees, about 15 per cent. from endowments, a little over 14.5 per cent. from grants from local education authorities and 28 per cent. from the exchequer.

For an anthropological research expedition to the islands of Normandy, Fergusson and Goodenough, in British New Guinea, as we learn from the London *Times,* funds are being provided out of the Oxford University common fund and by several of the colleges. The work has been undertaken by Mr. David Jenness, of Balliol College, who proposes, unaccompanied, to spend a year amongst people who are admittedly cannibals. It is stipulated by the university, in contributing to the expedition, that the museum shall have the first offer of articles of interest which may be obtained. Assistance has been promised by the missionaries on Goodenough Island, including the use of a boat and native oarsmen. The first few weeks will be spent in cruising around the islands endeavoring to get on friendly terms with the people and in studying the trade relations. As the natives have sea-going canoes and trade with the neighboring coast and the island of Trobriand, 100 miles away, Mr. Jenness will endeavor to obtain the good will of one of the chiefs and settle down for about a year. Later he will proceed on a mission boat to Rossell Island, at the eastern end of the Louisiade Archipelago, to study some ethnological problems concerning the relationships of Oceanic peoples. Mr. Jenness has been provided with the latest scientific instruments, including a phonograph for recording native songs and speech.

UNIVERSITY AND EDUCATIONAL NEWS

The Institute of Anatomy of the Jefferson Medical College, erected at a cost of $125,000, by Mr. Daniel Baugh, was dedicated on September 26. Addresses were made by Dr. E. A. Spitzka, professor of applied anatomy in the college, and Dr. George A. Piersol, professor of anatomy at the University of Pennsylvania.

The late Dr. William Flynn, of Marion, has willed his entire estate, valued at about $30,000, to the Indiana Medical College, in which he was a member of the faculty for many years.

Among the public bequests made by Mr. George M. Pullman was that of $1,200,000 for founding and endowing the Pullman Free School of Manual Training at Pullman, Ill. This fund has increased to more than $2,500,000. The first step toward founding the school was the purchase, in 1908, of a campus of forty acres within the limits of the town of Pullman at a cost of $100,000. Mr. Laenas Gifford Weld, until recently professor of mathematics and dean of the faculty of liberal arts in the Iowa State University, was appointed principal in May and entered upon his new duties September 1. He will visit the leading technical and trade schools in this country and in Europe before the preparation of definite plans is undertaken.

The medical department of Tulane University announces the inauguration of a department of tropical medicine, hygiene and preventive medicine, beginning October 1, in charge of Dr. Creighton Wellman and staff. Laboratory courses, clinics and lectures will be given in the regular junior and senior classes;

in addition graduate courses are offered, for which certificates will be issued, counting toward special degrees to be created.

A NEW university is to be founded at Perth, Western Australia. Mr. Cecil Andrews, who represents the commission charged with carrying out the project, is at present visiting the universities of this country.

DR. GEORGE H. DENNY, president since 1902 and previously professor of Latin at Washington and Lee University, has been elected president of the University of Alabama.

DR. A. S. PEARSE goes to the St. Louis University School of Medicine as associate professor of biology.

AT the University of Maine, Mr. Earle O. Whittier has been appointed instructor in chemistry and Mr. Clayton Urey, instructor in physics.

New appointments in the faculty for the University of Montana for 1911–12 are as follows: Honorable John B. Clayberg, honorary dean and professor of Montana practise and mining irrigation law; H. W. Ballantine, acting dean and professor of law; Philip S. Biegler, assistant professor of electrical engineering; George H. Cunningham, instructor in mechanical engineering; G. A. Gross, instructor in engineering shops.

THE faculty of Middlebury College, Vermont, has increased from twelve to twenty-five in the last four years. There are eight new instructors this year, all but two of them filling new positions. These include: Avery E. Lambert, Ph.D., assistant professor of zoology, from the State Normal School, Framingham, Mass.; C. Allan Lyford, A.M., assistant professor of geology from Clark College; George H. Cresse, A.M., assistant professor of mathematics; Ray L. Fisher, assistant professor of physical education and director of athletics; Irving W. Davis, instructor in pomology.

DR. DUNCAN GRAHAM has been appointed lecturer on bacteriology at the University of Toronto.

DR. ALEX. FINDLAY, special lecturer at the University of Birmingham, has been appointed professor of chemistry in the University of Wales at Aberystwyth.

DISCUSSION AND CORRESPONDENCE

A CARBONIFEROUS FLORA IN THE SILURIAN?

UNDER the caption "The Oldest Silurian Flora" Dr. G. F. Matthews[1] has recently set forth geological conclusions and correlations, which, if true, mean nothing less than the condition implied by the above title.

History shows, even in the literature of geology and paleontology, that if error be reiterated with sufficient frequency and vociferation it will, unless disproved or controverted, gradually gain credence and eventually tacit acceptance. Sometimes, therefore, as in the present instance, so persistent is the erroneous utterance, it unfortunately becomes necessary to repeat the protest; and in order that the paleobotanical misinformation contained in Dr. Matthews's last article may not, as in some preceding instances, find unopposed entrance to the text-books, the common dogma of geology, it obviously becomes somebody's unpleasant duty to challenge his conclusions. This I regretfully do, the seemingly inane title of this note being an epitome of the issue.

It concerns mainly the flora and the age of the "fern ledges"—the "Cordaites shale" and the "Dadoxylon sandstones"—at St. John and Lepreau, near the Bay of Fundy, which Sir William Dawson more than forty years ago referred to the Devonian, and which Matthews now declares are, in part at least, Silurian. Soon after the publication of Dawson's papers mild protests were offered by Geinitz and several others at placing beds with such distinctly Carboniferous plants and insects in the Devonian. About thirty years later, when both the Devonian and the Carboniferous floras were far better known and their stratigraphic significance more definitely determined, opposition was again made by Mr. Robert Kidston, the highest British authority on the Paleozoic floras, and myself, each of whom had examined collections from the disputed beds. Each, wholly without knowledge of the other's views, at once referred the flora to the Carboniferous, both regarding the plants as probably belonging

[1] *Bull. Nat. Hist. Soc. New Brunswick*, No. 28, 1910, pp. 241–249.

to the Pottsville group, which covers the "Lower" and "Middle Coal Measures" of the British Isles. As to their Carboniferous age neither of us had any doubt; and I think I speak correctly for Mr. Kidston when I add that the extensive discoveries of the past ten years, though without exception confirmative of our correlations, can have made us but little more certain of our ground. In reply we have heard repeated the arguments of the "sixties," that the flora differs from all other Devonian floras because it is estuarine or marsh, and that the relative metamorphism and the stratigraphy of the beds unmistakably prove their Devonian age.

It is impossible here to give particulars or even the substance of the paleobotanical evidence. Briefly, it is clear that the flora comprises an association of genera characteristic of the Upper Carboniferous; that many of the species are identical with plants in the Pottsville of the Appalachian trough, while other forms differ no more than may naturally be expected in view of the remoteness and isolation of the basin; that all types characteristic of the Devonian, including estuarine and delta beds in other parts of the world, are absent; that the evidence of the associated animal fossils is in agreement with that of the plants; that the metamorphism is not greater than in the Rhode Island Coal Measures; and that, in this region of extensive Pleistocene and sea concealment, and of folding, faulting and metamorphism, the stratigraphic evidence presented is neither clear nor conclusive.

We are now told that the floras ("faunas") of the "fern ledges" are Silurian! They are said to differ from all other pre-Carboniferous floras because they are "delta" floras! To be more explicit, the plant-bearing delta deposits are correlated by him with other beds in different regions shown by their marine remains to be Silurian. The "Dadoxylon sandstones" are accordingly referred to No. 2 of the Mascarene Silurian series, while the "Cordaites shales" are said to belong to No. 3 of the same series. In other words, Dr. Matthews now concludes that the "fern ledges" are of Clinton and Niagara ages. By no process can he possibly be interpreted as permitting the youngest plant beds to be above the Helderberg. Hence, if any paleobotanist has at any time entertained sufficient confidence in the stratigraphic arguments to cause real anxiety lest the "fern ledges" might possibly be Devonian, the new stratigraphic "correlation" must certainly put him completely at ease.

The almost astounding faunal discoveries brought to light by Dr. Walcott in the Canadian Rockies should deeply impress on every paleontologist the virtue of conservatism; but the possible analogies with the "fern ledges" floras are very limited. The wonderfully preserved fauna exhibiting so wide a systematic range and such singular biologic relations in the Cambrian of Canada nevertheless comprises characteristic Cambrian fossils. On the other hand, to assume that under local environmental conditions (which there is no reason for regarding as unique) there were developed at one known spot in the world not only a group of identical genera in characteristic association, but also species in part identical with those later reproduced in the "Upper Carboniferous," the flora being largely composed of fern genera nowhere else known in pre-Carboniferous beds and devoid of all the Devonian and Silurian types supposed to be contemporaneous, is certainly going to the extreme in the doctrine of parallelism in development.

To return to Dr. Matthews's paper: The discussion of the "fern ledges" floras and their ages is supplementary to the announcement of the discovery, in beds correlated by Dr. Matthews with the No. 1 (Medina) division of the Mascarene series, at Beaver Harbor, New Brunswick, of an Arthrostigma flora. Arthrostigma has been regarded as characteristic of the Devonian. We shall therefore look forward with keen interest to the full publication with, let us hope, adequate illustration of this older flora. The new flora which is from a different region is said to have nothing in common with the "fern-ledges" floras, which include such common Carboniferous genera as *Calamites, Annularia. Astero-*

phyllites, Neuropteris, Alethopteris, Megalopteris, Pecopteris, Whittleseya and *Sigillaria*.

DAVID WHITE

PROFESSOR PUNNETT'S ERROR

IN Professor Punnett's admirable little book, entitled "Mendelism," there occurs an error of definition that ought not to go unnoticed. This error, which runs through the whole book, begins on page 2, where may be found this statement: "Among animals the female contributes the ovum and the male the spermatozoon; among plants the corresponding cells are the ovules and pollen grains."

The last half of the quoted sentence contains three distinct errors: (1) Half of the plant kingdom possesses no pollen grains nor ovules, yet its members have parts that correspond with the ova and spermatozoa of animals; (2) the ovules and pollen grains are not *cells* but each is a cell complex; (3) it is a gross mistake to regard the pollen grains and ovules of plants as corresponding with the spermatozoa and ova of animals.

The first two mistakes might be passed over; but the third, in a book that is written for the reading public, is unfortunate and should be corrected in the next edition. The pollen grain is multicellular and the ovule is multicellular. The genetic cells of higher plants are produced in these bodies. It is as correct to call the testis of an animal a gamete as to call a pollen grain a gamete. The terminology of the genetic cells in plants need offer no difficulty to the zoologist. If he will consult the literature, or his botanical friends, he will find that, besides using the term *gamete* for the conjugating cells of both plants and animals, he may use *ovum* and *spermatozoon* for plants as well as for animals.

F. C. NEWCOMBE

PHENOMENA OF FORKED LIGHTNING

As pointed out in a recent paper in SCIENCE, September 1, the negative end of a lightning discharge is forked. When visible we call it forked lightning. When such a system of drainage channels penetrates a shower of negatively charged drops, great differences in potential between drops not far removed from each other must be created. Before the flash the drops have approximately equal potentials. They then repel each other. Drops having radii of one mm. only need to be charged to a potential of 0.0031 volt in order that their repulsion for each other may balance their gravitational attraction.

As soon as the flash occurs these drops attract each other. They coalesce, and a brief dash of large drops of rain follows.

FRANCIS E. NIPHER

SCIENTIFIC BOOKS

A Study of Chiriquian Antiquities. By GEORGE GRANT MACCURDY. Memoirs of the Connecticut Academy of Arts and Sciences, Vol. III., March, 1911. New Haven, Conn. Pp. 249, 384 text figures, 49 plates.

In a beautiful volume Dr. MacCurdy has given us the fruits of a long and patient investigation of the excellent collection of antiquities from Chiriqui in the Museum of Yale University. Not too much praise can be given to the painstaking examination and clear description of the long series of specimens, to the careful grouping of the material, which makes it possible for the student to master the wealth of new material with comparative ease. The author's description is about the same as that given by Holmes, but with a few modifications in terminology and grouping. Together with Professor Putnam's paper on conventionalism in ancient American art, and Professor Holmes's earlier description of ancient art of the province of Chiriqui, we have here material that needs only the additional researches of the field investigator to give us a clear picture of the archeology of a part of the Isthmian region. It is fortunate that, for a comparison of cultural types, the archeologist has at his disposal the two careful investigations by Dr. Hartman on the eastern and western parts of Costa Rica.

The illustrations in Dr. MacCurdy's volume are of the excellence of all the work of Mr. Rudolf Weber, whose illustrations of the publications of the Heye Expedition and for-

merly of the publications of the American Museum of Natural History have won him well-merited recognition on the part of the students of anthropology.

The author treats in detail work in stone, pottery and work in metals. The principal part of the work is devoted to a discussion of pottery forms and decoration, and the work must be considered an important contribution to the study of decorative art. I think in this lies its greatest interest.

Although the author does not commit himself quite definitely in regard to any theory of the development of art, his inclination, as exhibited in the detailed discussion of specimens, is clearly to consider geometrical ornament as developed by conventionalization of realistic motives, and he seems to consider this process as occurring by an inner necessity. "If the line of art development were plotted, it would probably be found to rise rather suddenly to the acme of realism, and then drop slowly to about its original level. The accompanying series of illustrations, however, does not begin at the beginning, but rather at the crest of the realistic wave, and descends gradually to the trough, probably that one lying on the conventional side; yet some of the stages shown might just as well be steps in the ascending as in the descending scale. In other words, a definite chronological sequence has not yet been established" (p. 57). Still in the next sentence the author states that there are reasons for considering realistic animal forms as preceding conventionalized forms, but I have not been able to find these reasons. Only in the case of the transformation of simple forms of objects into life forms does he admit the inverse process. "We have now followed the various steps in the development of the complete zoomorphic unit from the commonplace mealing stone" (p. 30). "It did not require a wide stretch of the imagination to arrive at the zoomorphic possibilities of the plain tripod leg. By the application of nodes and pellets of clay to the hollow tripod supports they immediately assume animal forms" (p. 51).

The difficulty in proving or disproving these theories lies in the fact that the material studied is not dated, that we do not know whether some forms are older than others, or whether all belong to the same time. That changes of artistic style have occurred in these areas is more than likely, notwithstanding the meagerness of proofs of cultural sequences on our continent. Dr. Spinden's demonstration of changes in the technique of an art style in Central America, the analogous phenomena observed among the cruder civilizations of the northwest coast, are important from this point of view which should receive the closest attention of archeologists.

It seems to the mind of the writer that the chief objections to the attempted interpretation of the development of an artistic style from a study of the undated object alone lie in the formal character of the treatment of the problem. Dr. MacCurdy, like his predecessors, has given us a careful classification of form and ornament, arranged according to considerations of technique, and of greater or less complexity of form. Among these he selects the forms which seem most plausible as the starting point of the series and the rest are then arranged in order, a time sequence being substituted for a series based on similarities of form. It may be that the investigator happens to strike the correct arrangement, but, considering the complexity of the problem and the possibilities of development in various directions, the probability of having reached a true historical explanation is not very great.

Dr. MacCurdy sums up the series of processes that lead to conventionalization as due to reduplication, exaggeration, elimination or fusion of parts of units; transposition, shifting and substitution; isolation of parts and their use independently of the whole; wholesale reduction and simplification; adaptation to fit a given space (pp. 127, 229). All these may occur, but they do not prove a historical development, because they are merely an enunciation of the principles of classification or seriation chosen by the student.

Wilhelm Wundt, in his Völkerpsychologie,

has pointed out that in our studies of development of art the psychological processes of the artist are the essentials for a clear understanding of the history of art, and I think this point of view must be kept in mind constantly if we desire to understand the history of art development.

For this reason it seems to me that the purely classificatory method, as followed by Dr. MacCurdy as well as by previous students, is not likely to give us the desired clue. Neither can it be found in ethnological inquiry and the most copious explanatory notes, which must always be open to the suspicion of having been read into the designs by the natives.

We have to bring before our minds more clearly the procedure of the native artist, the conditions under which he works and the extent of his originality. The term conventionalization, which we so readily employ, should be taken in a stricter sense, and we must understand what happens in the mind of the artist—including under this term unconscious processes—who either conventionalizes a realistic representation or develops a realistic form out of a geometrical form. Thus the problem presents itself of discovering the fundamental art forms that exert a domineering influence over the artist.

From this point of view, it seems to my mind that the first element to be determined is what is stable in each art form. Dr. MacCurdy does this in his careful classification of the material; and the association between lack of painting and presence of attached decorative elements modeled in the round,—a conclusion which I think has quite a general validity;—the presence of painting and lack of relief decoration; and other more detailed characteristics of certain forms, like the presence of the rim in vessels with neck decoration are brought out clearly.

The next step in the discussion of the ware with attached ornaments, however, does not seem to me well taken. Dr. MacCurdy points out the great frequency of armadillo-like forms, and the peculiar character of carapace, foot, eye and tail ornaments. From these he concludes, if I understand him rightly, that the life motive is older than the elements just described, which are derived from it. The relationship of the ware with relief decoration to analogous types of neighboring districts does not seem to me to favor this view. It is the essential characteristic of all this ware, that the decorative elements consist of small nodes or fillets which are applied to the surface of the vessel or to some of its parts, like feet, neck, shoulder or handle; and which are decorated by a series of short parallel impressions. An oval node with single medial lines is often used to indicate an eye; a similar nodule with a number of parallel lines indicates the foot, a series of parallel, short fillets with parallel short crosslines, are applied to the bodies of animal forms, but also to the bodies of vases. Hartman[1] describes analogous technical motives from Chircot and Orosi in Costa Rica (for instance Pl. 22, Fig. 2; Pl. 27, Fig. 2; Pl. 37, Figs. 5, 6; Pl. 39, Fig. 1; Pl. 51, Fig. 8; Pl. 64, Fig. 7) which in technical character are so much like the Chiriqui specimens that we can hardly doubt that they are derived from the same device. It might seem that this method of decoration is so easily discovered that little weight can be attached to it. Its extended use in South and Central America and in the West Indies[2] is, however, quite characteristic of that area. In North America it is not common, except in the Gulf region.[3] In contrast with its frequency in the highly developed pottery of Central America its almost complete absence may be noted in Africa, where highly decorated pottery forms are by no means absent, and where lids with animal figures might seem to suggest readily

[1] C. V. Hartman, "Archeological Researches in Costa Rica," Stockholm, 1901.

[2] See, for instance, W. J. Fewkes, "The Aborigines of Porto Rico," 25th Annual Rep. Bur. of Amer. Ethnology, Fig. 36, p. 185; Pl. 76, Fig. *c*; Pl. 78; Pl. 79.

[3] G. P. Thruston, "The Antiquities of Tennessee," p. 146; Pl. 7; W. H. Holmes, "Aboriginal Pottery of the Eastern United States"; for references see index under "fillets" and "nodes."

the application of the device.[4] This is true also of the prehistoric pottery of Europe. Only in the slip (barbotine) decorations of the terra sigillata do we find anything resembling the American appliqué ornamentation, but since the material is applied in a semifluid state, it does not attain the same freedom of treatment. Nodes that do occur in European prehistoric pottery seem to have been made rather in imitation of punched bronze decorations and belong to a late period. Attached animal figures, made in clay, like those found at Oedenburg, also seem to be imitations of metal work and have never reached that development which is so characteristic of Central American ceramic art.[5]

The characteristic slit rattle feet of Chiriqui pottery prove even more conclusively than the application of fillets and nodes, that the art forms of this province must be considered as a special development of forms characteristic of a much wider area. This type of foot is so well known that no special reference to its occurrences outside of the Chiriqui territory need be given.

We are thus led to the conclusion that the armadillo motive of the author is historically related to the method of decorating and building up vessels from separate pieces, nodes and fillets, the nodes and fillets being in many regions decorated by parallel incised lines, or by dots. If this is true, the armadillo motive can only be a specialized application of the building up of animal motives from the elements in question, and neither can the elements themselves be considered primarily as symbols of the armadillo (p. 61), nor can all the animals built up of these elements be interpreted as armadillos.

[4] "Notes analytiques sur les collections ethnographiques du Musée du Congo," Vol. II., "Les industries indigènes"; Part 1, "La céramique." (Fig. 293 *a* is the only one that may exhibit this technique.)

[5] Relief ornaments consisting of fillets have been described from northern Germany, Bohemia, Bosnia and Italy. See, for instance, Radinsky, Butmir, Vienna, 1895; K. Koenen, Gefässkunde, Bonn, 1895, Pl. III., Fig. 12.

For the same reason I am inclined to doubt the correctness of the interpretation of the alligator group, which was first given by Professor Holmes in the work before referred to. The upturned snout, of which much is made as a means of identification, is a character of much wider distribution than the alligator motive. The monkeys on Plates 27 and 32*a* of Dr. MacCurdy's book have it, and we find it as well in the interior of Costa Rica[6] as in parts of South America. This is no less true of the curious "nuchal appendage" which occurs in Costa Rica[7] as well as in South America,[8] and of the dotted triangle.

It seems to me that the essential point of this consideration lies in the technical and formal motives that are common to a large area, although differing in details in its provinces. These are the materials with which the artist operates and they determine the particular form which a geometrical motive or a life motive takes. If the notched fillet and node are the material with which the hand and the mind of the artist operate, they will occur in all his representations. If the conventional outline of the animal body has a definite form, all animals will tend to be represented in that manner. I have tried to emphasize at a previous time[9] the importance of such fixed traditional forms in determining the conventional style of decorations.

In his further descriptions of the art work of Chiriqui Dr. MacCurdy notes the similarity of motives used in metal castings, notably

[6] Hartman, *l. c.*, Fig. 2, Pl. 35, Pl. 81, Fig. 286, p. 128. The region in question has more frequently a proboscis-like appendage, rolled downward.

[7] Hartman, *l. c.*, Fig. 2; Pl. 35.

[8] M. H. Saville, "Contributions to South American Archeology." The George G. Heye Expedition. "The Antiquities of Manabi, Ecuador," Pl. 8. See also E. Seler, "Archäologische Untersuchungen in Costarica," *Globus*, Vol. 85, 1904, p. 237.

[9] Notes to G. T. Emmons, "The Chilcat Blanket," *Memoirs of the American Museum of Natural History*, Vol. III., Part 4, pp. 355 et seq.

in the gold castings, and the armadillo pottery, a similarity which consists essentially in the use of detached figures, nodes and fillets, as described before. He also calls attention to the frequent occurrence of the head with upturned snout—the alligator-head design of painted pottery—in this technique, a feature that had escaped the attention of previous students. At least one of them has, however, the type of proboscis rolled down (Pl. 58, Fig. *g*) which is so common on the plateaus of Costa Rica. In this case also the rigidity of the fundamental form seems particularly suggestive to the writer, because a variety of animals have all been presented in analogous outlines.

Franz Boas

Columbia University

Principles of Chemical Geology. A review of the Application of the Equilibrium Theory to Geological Problems. By James Vincent Elsden, D.Sc. (London), F.G.S. London and New York, Whittaker and Co. 1911. 222 pages, with 44 figures.

While an imaginative geological writer has recently asserted that "to be more productive than it is, geology must become more speculative," it is gratifying to note the steady advance that is being made in the explanation of geological phenomena along the lines of established principles in the fundamental sciences of physics and chemistry. With the rapid development of physical chemistry there has been a corresponding improvement in conceptions regarding processes that have taken part in the production of the earth as we know it. And every effort that is made to place these fundamental concepts within the reach of students of geology, and which succeeds as well as the book before us, should be welcomed as a contribution of the first order to the advancement of the science.

But it must be borne in mind that any developing branch of human knowledge is an assemblage of observations and conclusions of variable degrees of accuracy and truthfulness, subject to constant revision and readjustment. And in the problem of the application of principles of physics and chemistry to the phenomena of the earth, as a whole, and in detail, these are the variable factors of divergent opinion regarding the laws to be applied, and the still very inadequate data relating to the phenomena to be explained, as well as an accumulation of conflicting observations and of conclusions, in some instances misleading or actually incorrect. Moreover the multitudinous requirements in each branch of learning prevent the worker generally from acquiring independent judgment in more than one distinct branch of science.

For these reasons each contribution to the solution of the highly complex problems to be found in the study of rocks and minerals must have its particular characteristics arising from the point of view and range of experience of its author, as well as from the source of his information and the quality of his judgment.

In the contribution made by Mr. Elsden there appears to be the experience of a physicist familiar with the subject of physical chemistry, and capable of presenting the essential principles in a clear and simple manner, not wholly free, however, from the technology of the science. There is less of the chemical side of the subject than the title of the book suggests, which might better have been "Principles of Physical Chemistry Applied to Geology," for there are phases of the chemistry of the earth not touched upon. The application of the principles discussed is well made in most cases, and the examples that may illustrate them are happily chosen from the mass of recorded observations to be found in the literature of geology and petrology. In the selection and rejection of conflicting opinions in certain instances the author's judgment has been on the side of the more probable—according to the opinion of the reviewer. But the author does not appear to possess personal knowledge of the petrographical and mineralogical data appealed to in illustration of particular principles.

The author states that one of the main objects he has had in view is to show that the

key to the solution of the problems in the physical chemistry of geology lies in the determination of the conditions of equilibrium of each set of actions, or states of existence, of the factors under discussion; and further that he has attempted rather to stimulate interest in this branch of geology than to provide a complete exposition of the subject. It appears that this attempt is eminently successful, and that students of geology and petrology will be greatly benefited by this presentation of the principles in question.

The book consists of 10 chapters dealing with (1) Equilibrium between the Crystalline and Amorphous States; (2) Equilibrium as Influenced by Viscosity; (3) Diffusion as a Factor of Equilibrium; (4) Surface Tension as a Factor of Equilibrium; (5) Vapor Pressure as a Factor of Equilibrium; (6) Equilibrium Conditions of Polymorphous Forms; (7) Equilibrium in Solutions; (8) The Eutectic Theory; (9) The Theory of Solid Solutions Applied to Geological Problems; (10) On the Conditions of Chemical Equilibrium in Geology.

Without undertaking to give a synopsis of the contents of these chapters, or to do more than express approval of the method of treatment with a recommendation that they be carefully studied by those interested in the subject, attention may be called to several instances in which the fallibility of the literature relied upon by the author may be illustrated, or to instances where it has been misinterpreted. In the Chapter on Viscosity the observation of Barus on the combination of water and glass at temperatures between 185° and 200° C. is cited, and the impression is given that it is an operation of unlimited applicability to all glasses. Whereas Barus subsequently found that other commercial glass did not combine with water under any conditions which his apparatus was able to impose. The general conclusion stated by Mr. Elsden as to the effect of water in solution in silicate magmas in reducing viscosity is, nevertheless, correct, as other observations have shown.

In connection with surface tension and its explanation of the growth of larger crystals at the expense of smaller ones the author has confused his citations by referring to a description of the obsidian at Obsidian Cliff, Y. N. P., by the reviewer, as containing a supposed application of the principle to the weathering of the laminated rock. There is no reference to weathering in the paper mentioned, and its author never entertained any such ideas as those implied in the comment by Mr. Elsden.

In the discussion of crystallizations in metastable and labile states of solution it is quite evident that the author is not relying on his own knowledge of rocks, but has been misled by the dogma of "first and second generations of crystals," when he states that "while the metastable state persists small crystals could not be produced," for nothing is commoner than seriate porphyritic fabric in igneous rocks, and the presence of various sized crystals of the same kind of mineral. His treatment of the subject of crystallization is not so satisfactory as that of other portions of his subject. And in the discussion of the amphibole and pyroxene series the lack of appreciation of the chemical phase of the problem is apparent.

Aside from these criticisms the book is a valuable contribution to the literature of geology, and should be studied by all who desire to understand the bearing of physical chemistry on the problem of the formation and alteration of minerals and rocks.

J. P. Iddings

THE RELATION BETWEEN THE COLORATION AND THE BATHYMETRICAL DISTRIBUTION OF THE CYCLOGASTERIDÆ

In a recent article in Science[1] Dr. H. B. Bigelow gives a résumé of a preliminary report[2] by Dr. Johan Hjort on the results of the

[1] July 7, 1911.

[2] *Geographical Journal*, Vol. 37, 1911, pp. 349–377, 500–523. Not seen by the writer.

Michael Sars North Atlantic expedition in 1910. Dr. Bigelow cites, as one of the important results of the expedition, the experiments undertaken to discover the depth to which sunlight penetrates below the surface of the ocean and the relation between this and the bathymetrical distribution of animals exhibiting certain types of coloration. Dr. Hjort found that the red rays are absent and the blue and violet rays present at 500 meters; at 1,000 meters ultra-violet rays are perceptible and at 1,700 meters no trace of light could be detected. The black fishes and red prawns taken in the daytime in temperate latitudes were from a depth of 500 meters or more, *i. e.*, below the penetration of the red light rays. In more northern latitudes these animals were taken nearer the surface. In these regions the red light rays probably do not penetrate so far below the surface. Above the 500-meter level the fishes were found to be "characterized by lateral compression, larger and often telescopic eyes, light organs and silvery sides." These facts led Dr. Hjort to suggest that the lower margin of the area penetrated by red light rays marks the border between two differently colored faunas. Dr. Bigelow, in support of this view, states that the *Medusæ* apparently can be divided into two color groups which overlap at 250 to 300 fathoms. The species above this level are characterized by little pigment and iridescence, and those below by red and brown pigment.

The same relation between the vertical distribution and the coloration was found to exist in the young. The young of some of the species spend their larval existence near the surface and do not exhibit the adult coloration, this being acquired as they increase in size and descend to the habitat of the adult. The young of other species develop in the same region in which the adults are found and acquire the adult coloration much earlier. The coloration and vertical occurrence are correlated from the earliest stages.

The writer, during the preparation of a monograph of the Cyclogasteridæ, has had occasion to trace out the correlation between the coloration and the bathymetric distribution of these fishes. The results obtained are of interest in connection with those obtained by Dr. Hjort and Dr. Bigelow and it seems opportune to present a general account of them in advance of the main body of the work.

In reviewing the results presented here it should be borne in mind that the records upon which they are based are very incomplete when compared with those available to Dr. Hjort. It should also be noted that Dr. Hjort's conclusions result from the study of the general fauna while those of the writer are based upon the examination of a single family. This may account for the difference in the conclusions arrived at. The methods employed by the *Albatross* are very unsatisfactory for the solution of problems dealing with vertical distribution. The dredge is sent down and hauled up open, catching forms through all the intervening depths. Unless the animals captured have some peculiarity of structure which indicates their habitat as being on the bottom it is impossible to decide at what depth they entered the dredge. The intermediate hauls are made at a depth of 300 fathoms and the net hauled up open. The absence of species from the intermediate hauls indicates that their habitat is below this depth, but how far below remains a mystery. Also records of the coloration of the fishes, as they first appear, are very seldom taken. The colors frequently change in spirits. The translucent reddish cyclogasterids usually become an opaque white. This restricts the conclusion that can be drawn from the study of such specimens.

The Cyclogasteridæ is a favorable group in which to work out the modifications of structure and color as the species become adapted to the deep sea. This is true because the family is abundantly represented at all depths from the tide pools down to 1,973 fathoms. About 42 species are known to inhabit depths of less than 100 fathoms, 49 inhabit the region between 100 and 500 fathoms and 34 the depths greater than 500 fathoms. Starting with the tide-pool species as the most primitive, we can readily trace out definite modifi-

cations of form, structure and color as the species became more and more modified by the environment of the deep sea. We will confine our attention to the modification of the coloration and the relation between this and the distribution of the species.

The Cyclogasteridæ consist of about 100 species. The majority of these are placed in three large genera. The genus *Cyclogaster* consists of about 30, *Careproctus* of 38 and *Paraliparis* of 21 species. The remaining genera are monotypic or consist of a few species. The vertical distribution and the coloration of the three large genera will be described first. This will be followed by a chart indicating the distribution and coloration of all the species of the family.

Before entering upon a discussion of the genera it is advisable to review briefly the factors which lend color to the different environments inhabited by these fishes. For our purpose the color of a tide-pool environment may be said to be due to three factors or groups of factors. These are: (1) sunlight, (2) organisms and their remains, (3) inorganic materials of which the bottom is composed. In the tide-pools the coloration of the second factor may appear to depend upon the other two factors. In the oceanic depths below the penetration of light and far above the bottom these two factors are absent. The color of the organic life, if protective, can not be dependent upon their influence. It is necessary to assume the presence of light other than sunlight. We know that there is such light as can be produced by light organs. It has been suggested that there is another source of light on the bottom of the ocean. The decomposing animal matter may give off a phosphorescent glow of such intensity that the large-eyed fishes may be able to detect objects.

The modification of the color factors of the environment is accompanied by a modification of the coloration of the fishes. The sunlight is more intense and the organic life more brilliantly colored in the tide-pools and shallow waters of the tropics than in the arctic regions. The difference in the intensity of the sunlight is accompanied by a difference in temperature, but we shall ignore all the factors which compose an environment except those that exhibit color. As we descend below the surface of the ocean the sunlight becomes less intense. The organic life becomes less brilliantly colored. The red light rays probably do not penetrate below 500 meters or 273 fathoms. It has been suggested that this depth marks the border between two differently colored faunas. Dr. Hjort found that the fishes above this depth are characterized by silvery sides and those below by black pigment. The black forms are found nearer the surface in northern latitudes. Where the 273-fathom level touches bottom and where it is far above bottom constitute two differently colored environments. If at this level the color of the bottom has an influence, then the color of the fishes inhabiting these two environments should be different. It will be shown on the following pages that the bottom-inhabiting species of cyclogasterids appear to be differently colored from the free-swimming forms. There is a certain depth in the ocean below which light fails to penetrate. This will be less in the arctic than in the torrid regions. Its importance in marking the region between two faunas remains to be carefully worked out.

Cyclogaster is a shallow water genus. The species are common in the tide-pools and shallow cold waters of the northern and southern hemispheres. At least 21 of the 30 species have been taken in less than 10 fathoms. Only 5 species have been taken from depths below 100 fathoms and 3 from below 200 fathoms. One specimen has been taken at 250 fathoms. It is thus seen that the genus is confined to the illuminated area of the oceanic waters. We may provisionally place the lower margin of the bathymetric distribution of the genus at the level at which Dr. Hjort found the red light rays absent, the 500-meter or 273-fathom level.

The species of the genus, with but three exceptions, have a similar type of coloration. The colors harmonize with those of the other shallow-water fishes of northern regions. The

species typically have a variegated coloration which consists of bars, blotches, lines and mottlings of white, slate, brown and black, the predominating colors of the fishes of northern regions.

The coloration of the deeper-water species is slightly modified by the environment. The variegated coloration is retained, but in addition to this, in two or three species, a reddish lining to the dermis and a silvery or a black peritoneum have been acquired. These are the colors predominating in the genus *Careproctus* which flourishes in regions between 100 and 500 fathoms. The vertical distribution of each species is important in considering its coloration. Species such as *Cyclogaster dennyi* and *Cyclogaster fucensis,* which extend from within 2 or 3 fathoms of the surface down to 123 and 212 fathoms, do not show an appreciable change in coloration.

Careproctus is the most interesting genus in the family. It has been derived from the shallow-water genus *Cyclogaster* and presents the first distinct modification of structure and color caused by the environment of the deep sea. It has given rise, directly or indirectly, to practically all of the other deep-sea genera. The distribution of the species extends from shallow water to great depths, or from 29 to 1,823 fathoms. The genus seems to flourish best in the region between 100 and 500 fathoms. Two thirds of the species are found in this region.

The coloration of species of *Careproctus* is very distinct from that typical of the species of *Cyclogaster*. None of the species are variegated. The nearest approach to this condition is that of *Careproctus cyclospilus* and *Careproctus mirabilis,* two shallow-water species, which have pink blotches over the body. The species are typically translucent, reddish translucent and black. In a number of species the posterior part of the body only is black. It appears that the black pigment encroaches upon the body from the caudal region anteriorly.

The species of *Careproctus* can be arranged in three color groups. These groups include the light-colored species, the black species and the species intermediate between these two. The light-colored group includes the translucent, whitish and reddish species. When placed in alcohol the translucent and reddish appearance is usually lost and the species become an opaque milky white. It is doubtful if any of the species are this color in life. In the black-colored group are included all the black species. In the third group are included those species which are dusky or have the posterior part of the body, the gill cavity, peritoneum or stomach black. The distribution of these three color groups will be considered separately.

The light-colored group, consisting of 27 of the 38 species of the genus, is represented in depths between 29 and 1,046 fathoms. The majority of these species are found between 100 and 500 fathoms. Six species are found in less than 100 fathoms and 4 below 500 fathoms. The distribution of the light-colored species apparently has no more relation to the 273-fathom level than to the 400-fathom level. Eighteen species are found above the 273-fathom level, 13 below it and 4 on both sides, while 22 species are found above the 400-fathom level, 10 below it and 5 on both sides.

The distribution of the remaining two groups of species does not indicate that the 273-fathom level marks the border between two differently colored faunas. The dusky species, of which there are 8, are found between 35 and 887 fathoms, but the majority have been taken between 300 to 500 fathoms. There are 3 species in the black group and these are all from below 405 fathoms.

The color of the peritoneum is of interest in connection with the color of the body and the distribution. The peritoneum is sometimes black when the epidermis is white, but apparently is never white or silvery when the epidermis is black. In preserved specimens it is sometimes difficult to decide whether the peritoneum was originally a dull white or silvery. It appears, however, that the silvery peritoneum is most common with the reddish translucent species. Dr. Hjort reports that the fish fauna above the 273-fathom level is characterized by silvery sides. A silvery

peritoneum in the translucent species of *Careproctus* gives these fishes somewhat the appearance of having silvery sides. The distribution of the species having a silvery peritoneum apparently is not influenced by the change in environment at the 273-fathom level.

The facts concerning the coloration and distribution of the species of *Careproctus* indicate that the 273-fathom level is of no greater, if of as great, importance than the 400-fathom level in marking the border between two differently colored faunas. The former level appears to be of little or no significance in the distribution of the light-colored species, while the latter level marks the upward limit of distribution for the black species and contains the largest number of species intermediate between white and black, *i. e.*, the dusky species.

The genus *Paraliparis* in structure, coloration and distribution is more of a deep-sea genus than *Careproctus*. The species of the genus may be placed in three color groups, but the proportion of the species in the groups differs from that in *Careproctus*. For instance only 8 per cent. of the species of *Careproctus* are black while 50 per cent. of the species of *Paraliparis* are of this color. All the species of *Paraliparis* have a dusky or black peritoneum. Only 25 per cent. of the species *Careproctus* have the peritoneum black. The species of *Paraliparis* typically inhabit greater depths than do the species of *Careproctus*. The high and low levels of distribution for the two genera are almost identical, but what may be termed the centers of population of the two genera differ. Half of the species of *Careproctus* are taken above and half below the 300-fathom level. The 500-fathom level holds the same relation to the distribution of the species of *Paraliparis*. We thus see that there is a difference of 200 fathoms between the centers of population of the two genera. There must be considerable difference in the amount of light present at these two centers of population. With this difference in the amount of light is associated the difference in the number of black forms in the two genera.

The relation between the coloration and the distribution of the species of *Paraliparis* is the same as in *Careproctus*. Without entering into much detail we will state that the 273-fathom level is of no significance in the distribution of the light-colored species. Only two of these species have been taken below this level. The distribution of the black species is interesting because, as in *Careproctus*, it extends from 400 fathoms downward.

The distribution of all the species of the family reinforces the conclusions that may be drawn from a study of the distribution of the species of the genus *Careproctus*. The chart indicates the coloration and distribution of all the species. It can be seen that the 273-fathom level marks the lower limit of distribution for the variegated species, but is of no significance in regard to the distribution of the light-colored, dusky or black species. The region at about 400 fathoms is of more importance. It marks the depth at which the light-colored species are reduced in numbers, and where the dusky species are the most common. It also marks the upper limit of distribution of the black species.

Depth	30	100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000
Variegated	23	11	4	3																	
Light	1	7	10	15	12	11	4	4	1			1									
Dusky		2	8	7	11	11	7	6	3	2	2	1	1	1	1	1	2				1
Black						3	2	3	1	2	3	3	1	1	1	1	2	1	3	3	

Chart illustrating the coloration and bathymetrical distribution of the Cyclogasteridæ. Species ranging through depths represented by several sections are counted in each section.

The facts just stated indicate that, in general, the coloration of the species of *Cyclogasteridæ* depend upon their bathymetrical

distribution. The question naturally arises: are these fishes protectively colored, or, is the color dependent upon the modification of structure or some other factor besides the color of the environment? The question is complex, because there is a parallel modification of color and structure due to the environment of the deep sea. It frequently happens that a certain type of structure is associated with a certain type of coloration. Also the coloration of the species sometimes appears to be independent of either the color of the environment or the type of structure. Those biologists who view with suspicion the attempts to explain the coloration of tide-pool fishes by means of the protective coloration theory will be even more skeptical toward any effort to explain the coloration of deep-sea fishes by means of the same theory. The factors of a tide-pool environment are spread out before us but those of the deep-sea are hidden. We do not know that there is sufficient light in the greater depths of the ocean to enable the fishes to see and of course without light there can be no protective coloration. If this is a region of total darkness the color of an animal can not be an aid to its concealment. So far as protection is concerned a fish may just as well be brilliantly colored as transparent or black. But they are not brilliantly colored. Instead they are typically of a uniform coloration, which is usually black. In the regions of dim light they are of another color. The coloration bears some relation to the depth at which the species exist. The amount of sunlight depends upon the depth and consequently the coloration appears to depend upon the amount of sunlight to which the species are subjected. There are two possible sources of light in the oceanic depths below the penetration of sunlight. We know that certain animals of this region have light-producing organs and the decomposing animal matter may give forth a phosphorescent glow. And, as if for the purpose of sight in a dim light, the eyes of the fishes have become greatly enlarged. Regardless of the merits of the protective coloration theory it furnishes us with a fascinating field for speculating. The attempt to explain some of the facts concerning the coloration of the Cyclogasteridæ by the protective coloration theory will not be amiss here.

The environment of the deep sea has had a different effect than the dark cave environment upon fish life. Dr. Eigenmann has made an exhaustive study of cave fishes. In these fishes the eyes atrophy and the pigment is reduced or absent. Dr. Eigenmann believes that we have here an example of the inheritance of an acquired characteristic. The case, as he so ably presents it, appears unassailable. The color of some of the cave fishes can not be protective, for there are no enemies to protect them from. The fishes of the deep sea are surrounded by other fishes with large eyes and long teeth. The presence of a light would allow the struggle for existence to become more intense. The effects of a cave environment and the deep-sea environment upon the coloration of fishes are similar up to a certain point and then widely diverge. The effects of the dimly lighted cave and the dimly lighted regions of the ocean lead to the reduction of pigment. The effect of a totally dark cave is to allow the fishes to lose all their pigment. In contrast to this the fishes in the ocean below the penetration of sunlight acquire pigment and become wholly black. Possibly the difference in the effects of the two environments can be explained by the protective coloration theory, which can not explain the coloration of cave animals but may explain the coloration of deep-sea animals.

The overlapping of faunas calls for further discussion if we are to consider the fishes as protectively colored. The genus *Careproctus* originated in moderately deep waters. From this region representatives of the genus migrated into shallower waters and down to great depths. Those that entered shallower waters retained their light and uniform coloration. Of those that descended to greater depths some retained their original coloration, but the majority became black. The species that entered shallow water became associated with the variegated species of *Cyclogaster*. The distribution of these two genera overlap be-

tween 29 and 250 fathoms. The association of species of the two genera may be more apparent than real, for the species of *Cyclogaster* are typically bottom-inhabiting forms and those of *Careproctus* free-swimming. The distribution of the light-colored and black forms overlap between 400 and 1,000 fathoms. The gradual merging of one environment into another and the force of heredity may account for the overlapping of the faunas, but, as is the case with the shallow-water species, the differently colored ones may not intermingle. Let us imagine a portion of the ocean bottom as illuminated by a lantern. A black fish on a dark bottom or near the margin of the illuminated area would be practically invisible. A transparent or a reddish translucent fish would be little more discernible. Away from the bottom and near the source of light a black fish would be more conspicuous than the others. At such depths it is difficult to decide which species rest upon the bottom and which swim freely some distance above it. The deep-sea Cyclogasterids, which, from their structure, we assume to be free-swimming, are nearly all light-colored. Nearly all of those which appear to live upon the bottom are black. It should be noted that among other deep-sea fishes a number of free-swimming species are black and also that some of the bottom-inhabiting species may be light-colored. It can be seen from the above discussion that the light-colored species in the depths below the penetration of sunlight may be as protectively colored as the black forms. The disparity in the numbers of light-colored and black species suggests that this is not true or that the majority of the species live upon or very close to the bottom.

The significance of the predominance of reddish color in the light-colored species is unknown. This type of coloration may be considered as being intermediate between the translucent and black types and having the partial advantages of both. In dealing with this question the color perception of the eyes of fishes should be taken into consideration. If the eyes of fishes lack the color perception of our own and are simply camera eyes the reddish species will appear gray and be inconspicuous in their environment.

We have intimated that, in addition to a change in coloration, the deep-water species become translucent. The tide-pool species are soft and flabby and no great change is required for them to assume a translucent jelly-like appearance.

In concluding I wish to express my appreciation of the work of the *Michael Sars* in 1910. The observation made on this expedition that the coloration and bathymetrical distribution of the young fishes are correlated from the earliest stages is confirmed by my work on the Cyclogasteridæ. The young of these fishes inhabit the same regions as the adults and are similarly colored. Dr. Hjort's suggestion that the 500-meter or 273-fathom level marks the border between two differently colored faunas does not harmonize with the conclusions I have reached from a study of the Cyclogasteridæ. The acquisition of more carefully taken records of these fishes resulting from expeditions as carefully planned as that of the *Michael Sars* may cause us to modify our conclusions concerning the importance of the 273-fathom level in relation to the distribution and coloration of the Cyclogasteridæ and bring them more in accord with those of Dr. Hjort.

Charles Victor Burke

Palo Alto, Cal.

SPECIAL ARTICLES

ISOSTASY, OCEANIC PRECIPITATION AND THE FORMATION OF MOUNTAIN SYSTEMS

The theory of isostasy postulates the uniformity of the weight of the earth's crust over the surface of the earth. It was suggested by Major Sutton[1] in 1889. It has recently received considerable attention by geodesists and geologists and has received quantitative confirmation by the researches of Hayford.[2] Recent work has been along the line of investigating the effect of displacement by erosion and the resulting equilibrium flow.

[1] *Bull. Phil. Soc. Washington*, 11: 51–64, 1889.

[2] See Science, February 10, 1911; also H. F. Reid, *Proc. Am. Phil. Soc.*, 50: 444–451, 1911.

No one appears to have considered the effect of oceanic precipitation in the middle geologic ages.

It is sufficient for this discussion to divide the earth's geologic history into three periods; the fluid age, the crust-steam age, and the crust-ocean age. During the crust-steam age the crust increased gradually from nothing at all to an effective thickness, including the layer of partial solidification, of several miles. During the larger part of this age, the water now forming the oceans was probably all in the atmosphere. The period of oceanic precipitation was probably quite extended on account of the heat liberated by condensation as well as the increased admission of solar radiation due to the clearing of the atmosphere.

At the time when liquid water began to exist in quantity, the cooling of the earth's crust had progressed far below the freezing-points of nearly all the materials of the crust, and the most plausible assumption is that the crust was of considerable thickness. It is also probable that the earth's surface was fairly level, the flatness depending upon the uniformity of distribution of rock materials of different densities.

Consider now the effect of superposing on this early crust a great quantity of material of low density, namely, the water of the oceans. Near the borders of the great oceans, we should then expect to find a severe outward thrust of crust comparable in mass to the mass of the ocean, but in volume less in inverse proportion to its density.

The isostatic conditions would further lead us to look for the accommodation to this displacement material farther inland, in a general continental elevation increasing toward and up to the border ranges.

This suggestion is put forward for what it may prove to be worth. Whatever may have been its consequences in detail, if the isostatic condition has been even approximately adhered to during the earth's history, the precipitation of the oceans must have had a profound effect on the elevation and depression of portions of the earth's crust. With more definite knowledge of the physical properties of geological materials it should be a mere mathematical problem to determine what those effects have been.

P. G. Nutting

Washington, D. C.,
September 12, 1911

MUSICAL ECHOES

The phenomenon of musical echoes has been known for a long time and has secured recognition in the text-books on sound. Thus we read:[1]

> Frequently, a sharp sound, such as the clapping of the hands or of two boards together, is reflected in a room or a corridor with smooth, parallel walls as a more or less musical sound. A similar effect is often observed when one is walking near palisading, each footstep of the observer being followed by a musical ring. The effect is only noted after some sudden sound, and may often be heard very distinctly on clapping the hands or on knocking two stones together.

The Greek Theater at the University of California presents a pronounced musical echo, the conditions being especially favorable to the production of the phenomenon. The seats are made up of a series of large concrete steps that are semicircular in shape and that rise regularly towards the back. If an observer generates a sharp sound in front of the stage at the center of the circles of steps the sound passes out symmetrically and strikes the steps in perpendicular planes and is reflected and diffracted back to the source of sound. The pulses of sound reflected from the successive steps follow each other regularly and thus set up a musical sound which is heard by the observer.

It occurred to the author that the pitch of the sound might be determined. The method of experiment was to generate a musical echo as already described and to compare the pitch of this sound with that of an adjustable turning fork. A check on the final result was found by calculating the pitch from the relation $n = v \div \lambda$ where n is the pitch of the sound, λ the wave-length and v the velocity of sound at the temperature of the theater. It is

[1] Poynting and Thomson, "Sound," pp. 31, 32.

to be noted that the wave-length is equal to *twice* the width of the steps (see Fig. 1). The advancing wave of sound *xy* strikes the first step and part of the wave is reflected. When *xy* reaches the second step, the sound from the first step has already traveled back a distance equal to the width of the steps. Therefore, the distance between the reflected pulses of sound—the wave-length—is equal to *twice* the width of the steps. It should be noted also that this phenomenon shows clearly the diffraction of sound. The fact that an observer can hear the separate pulses of sound at any point in front of the steps, indicates that the sound must spread out from each step as a center of disturbance.

The results of the observations follow. The observed pitch as determined by an adjustable Koenig fork was 226 vibrations a second. The pitch was calculated from the relation $n = v \div \lambda$ from the following data. The observed temperature was 22° C., hence the velocity of sound[2] was $v = 33{,}200 + 61 \times 22 = 34{,}542$ cm./sec. The width of the steps was 76 cm., hence $\lambda = 2 \times 76 = 152$ cm. Finally $n = 34{,}542 \div 152 = 227$ vibrations per second.

The agreement between the observed and calculated values is closer than one would expect. The pitch of the fork was not corrected for temperature. Another source of error lies in the fact that the outgoing pulse of sound struck the steps at an angle rather than perpendicularly, so that the wave-length was somewhat greater than twice the width of the steps.

A second example of a musical echo was observed when a sharp sound was reflected from a set of bleachers on the athletic field at the University of Illinois. The pitch was determined, as in the former case, although the conditions were different and not so favorable. The bleachers were constructed of wood and were situated in a long straight row. If a rifle was shot off at some distance in front of the bleachers, an observer heard the reflected musical echo distinctly. The data taken follows. Temperature = 25° C., velocity of sound 34,725, width of steps = 73.5 cm., $n = 236$ vibrations per second. The pitch as observed by a tone variator was 235, although other observers nearer the bleachers obtained a value 241. The agreement between the calculated and observed pitches is as close as could be expected.

Aside from the novelty of the experiment, it is interesting to learn that the pitch of the echo is so definite. The notes given out in both cases cited is about a tone below middle C, hence where an observer expects a musical echo from steps about 30 inches wide, he can anticipate the result very nearly by first humming the expected tone.

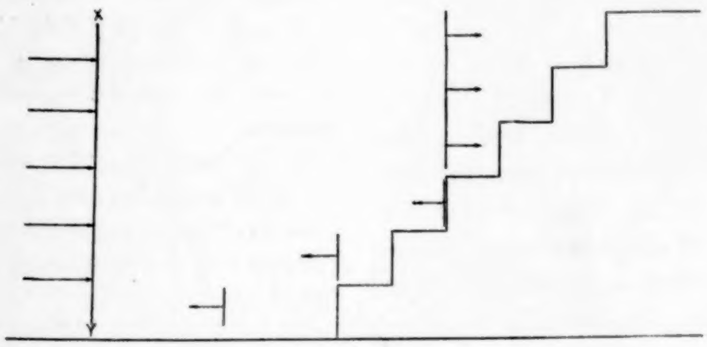


FIG. 1

F. R. WATSON
UNIVERSITY OF ILLINOIS,
May 17, 1911

[2] Poynting and Thomson, "Sound," p. 21.

SOCIETIES AND ACADEMIES

AMERICAN MATHEMATICAL SOCIETY

THE eighteenth summer meeting of the American Mathematical Society was held at Vassar College on Tuesday and Wednesday, September 12–13, extending through two ses-

sions on Tuesday and a morning session on Wednesday. Thirty-two members were in attendance. Ex-presidents Thomas S. Fiske and Henry S. White occupied the chair in alternation. The council announced the election of the following persons to membership in the society: Professor Frederick Anderegg, Oberlin College; Dr. C. E. Brooks, Northwestern University; Mr. G. G. Brower, Cascadilla School; Mr. W. C. Graustein, Harvard University; Dr. Dunham Jackson, Harvard University; Mr. W. V. Lovitt, University of Washington; Mr. J. C. Raysworth, Washington University; Mr. L. L. Smail, University of Washington; Dr. E. B. Stouffer, University of Illinois; Dr. S. E. Urner, University of Wisconsin; Professor J. N. Van der Vries, University of Kansas; Mr. C. W. Webster, University of Washington. Twelve applications for membership in the society were received. The total membership is now 658.

Luncheon was served by the college on both days. On Tuesday evening twenty-nine members gathered at the usual informal dinner, at the close of which brief remarks were made by Professor Birkhoff on Moore's general analysis and by Professor A. G. Webster on wider views in mathematics and physics. Wednesday afternoon was devoted to an excursion to Lake Mohonk. At the close of the meeting the hospitality of Vassar College was recognized by a vote of thanks.

The following papers were read at the summer meeting:

Edmund Landau: "Ueber eine idealtheoretische Funktion."

W. A. Hurwitz: "On the pseudo-resolvent to the kernel of an integral equation."

W. A. Hurwitz: "On mixed linear integral equations."

Elizabeth R. Bennett: "Simply transitive primitive groups whose maximal subgroup contains a transitive constituent of order p^2 or pq, or a transitive constituent of degree 5."

Florian Cajori: "On a rare book of Michel Rolle and the history of 'Rolle's theorem.'"

L. C. Karpinski: "The Algebra of Abū Kāmil Shojā ben Aslam."

F. W. Beal: "Normal congruences determined by centers of geodesic curvature."

Arnold Emch: "On the congruence of rays realizing circular transformations between two planes."

Joseph Bowden: "The two fundamental relations of the calculus."

J. E. Rowe: "Covariant curves of the R^4 and R^5."

G. A. Miller: "A third generalization of the groups of the regular polyhedra."

G. A. Miller: "Some properties of the group of isomorphisms."

L. P. Eisenhart: "Minimal surfaces in plane four-space."

Arthur Ranum: "On the projective differential geometry of spreads generated by ∞^1 flats."

E. W. Castle: "A graduation of the combined experience table of mortality to Makeham's formula by the method of moments."

S. Lefschetz: "On the existence of loci with given singularities."

S. Lefschetz: "On some topological properties of plane curves."

Virgil Snyder: "Periodic quadratic transformations in a ternary field."

A. G. Webster: "On a new mixed boundary problem in connection with the telegrapher's equation."

A. G. Webster: "On the wave potential of a circular ring of sources."

A. G. Webster: "Solid viscosity versus elastic hysteresis in the transverse vibration of an elastic bar."

G. D. Birkhoff: "New proof of the theorem concerning matrices of analytic functions."

G. D. Birkhoff: "On the simplest type of irregular singular point."

G. A. Bliss: "A generalization of the preparation theorem for a power series in several variables."

Oswald Veblen: "On the definition of multiplication of irrational numbers."

H. T. Burgess: "One-parameter groups of contact transformations defined on a fixed quadric by a bilinear form."

Joseph Bowden: "Making a recitation schedule."

The next meeting of the society will be held at Columbia University on Saturday, October 28. The San Francisco Section will meet on the same day at the University of California.

F. N. Cole,
Secretary